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GUIDE BOOK No. 8

TRANSCONTINENTAL EXCURSION C 1

TORONTO TO VICTORIA AND RETURN
VIA CANADIAN PACIFIC
AND CANADIAN NORTHERN
RAILWAYS

PART II

GEOLOGICAL SURVEY
DEPARTMENT OF MINES
OTTAWA
1913

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Toronto to Victoria and return via Canadian Pacific and Canadian Northern Railways

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Part II.

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INTRODUCTION TO THE GEOLOGY OF THE CORDILLERA.

BY

REGINALD A. DALY.

GENERAL TOPOGRAPHY.

The North American Cordillera, extending from Bering Sea to the intersection with the Antillean mountain system, has a length of 7,000 kilometres (4,350 miles), an average breadth of about 900 kilometres (560 miles), and an area more than two-thirds that of all Canada and nearly two-thirds that of Europe. This gigantic feature of the earth is a tectonic unit, originating in stresses specially exerted from the Pacific basin. The Cordillera as a whole has, therefore, been fitly called the Pacific Mountain system of North America.

The members of Excursion C1. will cross the system where it is comparatively narrow; nevertheless, a straight-line measurement of its width is here about 700 kilometres (435 miles). Along the somewhat tortuous route of the Canadian Pacific railway, the distance from the eastern foot of the mountains to the city of Victoria is 1,050 kilometres (650 miles). For purposes of geological description and of orientation in the field, it is necessary to review the general subdivision of the Pacific Mountain system at the railway section.

Among the conceivable criteria for subdivision, the purely topographic principle used by G. M. Dawson seems to be the only practical one. In the first place we may distinguish a belt characterized by plateau forms and thereby contrasted with the rest of the Cordillera in the Dominion of Canada. This may be called the Belt of Interior Plateaus. It lies on the eastern side of the Coast range, which is of alpine habit. Elsewhere the subdivision of the mountain chain follows the lines of the master valleys.

The greatest of the intermont depressions is that extending from Flathead lake in Montana to the Yukon boundary, a distance of 1,600 kilometres (990 miles). It is a relatively narrow but actually imposing trough, successively drained by head-waters of most of the great rivers of the

Sketch map showing major subdivisions in the southern part of the Canadian Cordillera.

Canadian part of the chain: namely, the Columbia, Fraser, Peace and Liard—the last two being principal branches of the Mackenzie river. The larger streams flowing in the depression are: the Kootenay; the Columbia; the Canoe river; the Fraser; the Parsnip and Finlay rivers (Peace river system); and the Kachika river of the Liard system. Many of them leave the trough by transverse gorges cut in the adjacent mountains. The rivers enumerated, as well as smaller ones not specially named, are arranged in regular sequence, draining the trough in opposite (N.W. and S.E.) directions. Although continuous throughout its great length, the trough is not a valley in the ordinary sense. It is like a trench dug by soldiers in a hilly country; such a defensive work is not cut to a uniform bottom grade but is man-deep whatever the slope. This master form in the Cordillera may be appropriately described as a topographic trench. All the mountains in Canada and in Montana lying to the north-eastward of the trench have long been segregated as the Rocky Mountain system, and the bounding trough has been named the *Rocky Mountain trench.*

A second trench, about 350 kilometres (220 miles) in length, opens in the southeastern wall of the first near Beavermouth and runs southward. It is successively drained by Beaver river, Duncan river, and Kootenay river; for 120 kilometres (74 miles) it is occupied by the fiord-like Kootenay lake. This trough rigorously separates the Purcell Mountain range on the east from the Selkirk system on the west and bears the name, *Purcell trench.* The Purcell range is thus bounded, east and west, by the two trenches; on the south it terminates at the loop of the Kootenay river in Montana and Idaho.

Near latitude 52° the Columbia river leaves the Rocky Mountain trench and flows south, in a wide valley 500 kilometres (310 miles) long, to the Columbia lava-field of Washington State. This part of the Columbia valley may for convenience be called the *Selkirk valley.* Midway in its course it bears the Arrow lakes, totalling 150 kilometres (92 miles) in length. East of the Selkirk valley and west of the two master trenches is the Selkirk Mountain system which, like the Rocky Mountain and Purcell systems, extends into the United States.

The rugged mountains to the west of the Selkirk valley have been grouped under the name, Columbia

Looking southeast from Six Mile creek along the Purcell Trench (Beaver River valley).

mountain system. On the north this system is bounded by the obliquely truncating Rocky Mountain trench; and on the south by the lava plateau of Washington. Toward the west the Columbia mountains become less alpine and assume a rough-plateau character, so that it is not possible to make a clean-cut line of division from the adjacent Belt of Interior Plateaus. This zone of topographic transition is crossed by the railway in the region of the

Looking south from Terminal Peak along the edge of the great escarpment bounding the Purcell Trench on the west.

Shuswap lakes. The Fraser valley at and in the vicinity of Lytton forms a convenient and more definite limit to the Belt of Interior Plateaus, on the west.

The Coast range extends from the Fraser valley to the structural depression occupied by the Strait of Georgia and Queen Charlotte sound, to the westward of which is the Vancouver range of Vancouver island. On the south the Coast range terminates at the transverse portion of the Fraser valley, which also delimits the Cascade range entering British Columbia from the United States.

In the larger view, the Canadian Cordillera may be broadly divided into four provinces: (a) the Rocky Mountain system; (b) the Middle or Interior ranges, including the Purcell, Selkirk, Columbia and Cariboo mountains; (c) the Belt of Interior Plateaus; and (d) the Coastal system, including the Coast range, the Cascade range, and the Vancouver-Queen Charlotte range. The first, third, and fourth of these provinces extend, with but minor interruptions, through Yukon Territory and Alaska to Bering Sea. The Middle ranges as a whole are specially broad in southern British Columbia, but narrow rapidly to the northward and, in the United States, have been broadly depressed and covered by the lava floods of Idaho and Washington states.

GLACIATION OF THE CORDILLERA.

The field habit of the visible glaciated rock-surfaces and the condition of the drift deposits, in these Canadian mountains, strongly suggest that the great glaciers of the Cordillera were essentially contemporaneous with the eastern ice-cap at its Wisconsin stage. No facts yet determined on the mainland of British Columbia or in Alberta have shown clearly that general Pleistocene glaciation was multiple. It is true that, at many points within the Cordillera and along its piedmonts, younger till rests on water-laid silts, sands, or gravels of Pleistocene age; but this relation is that normal to the inevitable oscillation of ice-fronts during a single glacial period and it is still unsafe to postulate a general interglacial epoch for the Cordillera. However, further investigation of its interior portion may demonstrate one or more interglacial periods, even in spite of the fact that, in a topography so strongly accidented, a more recent glaciation must tend to obliterate the traces of an earlier one.

When at their maximum, the Pleistocene glaciers of the mainland formed an interior ice-cap flanked by double rows of valley glaciers. The ice-cap was fed by the local sheets respectively draining the western versant of the Rocky Mountain system and the eastern versant of the Coast range. The eastern slope of the Rockies was drained by many large valley glaciers. These often became confluent as piedmont sheets on the plains of

Alberta. Similarly, the western slope of the Coast range bore heavy glaciers which formed thick and broad piedmont sheets filling Puget sound, the Strait of Georgia, and Queen Charlotte sound.

Dawson located the main accumulator of the ice-cap in the interior of the Cordillera between latitudes 54° and 59°, and proved the northward flow from that region as far as 63° N., as well as a southward flow over the 49th parallel into Washington State. Locally, the ice-cap sent thick distributary sheets through low cols and valleys crossing the Coast range; of these the Fraser valley is a signal instance. At many points the surface of the en- era ice-cap is known to have risen somewhat above the 7,000-foot (2,134-metre) contour. Its thickness at the Okanagan valley was at least 6,000 feet (1,830 m.); at Revelstoke about 5,500 feet (1,677 m.).

Nothwithstanding its massive proportions, the ice-cap performed comparatively little erosion. Area for area, this necessarily sluggish body was incomparably less powerful in cutting into bed-rock than were the neighbouring valley glaciers. These were usually much swifter because occupying lines of more concentrated flow. The influence of such concentration, caused by mountainous topography, is extremely clear in the Canadian Cordillera, and the principle leaves no ground for controversy as to the efficiency of glacial erosion.

A smaller, independent ice-cap covered Vancouver island, and another, or else a large number of local glaciers occupied the Queen Charlotte islands.

GENERAL STRATIGRAPHY.

The section along the Canadian Pacific railway offers an almost complete representation of the main rock systems known in the Canadian Cordillera. The variety of the formations is explained partly by the transverse character of the section through a belted mountain chain; partly by the specially extensive uplift and exposure of the oldest rocks in this geological province. Only the Pliocene and the Miocene fail to appear in the list of standard rock systems, which here ranges from the Pre-Cambrian (pre-Beltian) to the Pleistocene. In the succeeding table the more important formations, with thicknesses, are named in

order. The measurements and estimates are founded on considerable, more recent field-work supplementing the reconnaissance studies of G. M. Dawson. [**5,** p. 62].

The total of the maximum thicknesses is colossal (135,000 feet (41,150 m.), including 25,000 feet (7,620 m.) of volcanics), but there can be no doubt that it is correct as to the order of magnitude. Notwithstanding all possible errors of mensuration, it seems clear that the Beltian-Paleozoic geosynclinal prism of the Selkirk-Rocky Mountain region had a thickness greater than 50,000 feet (15,240 m.). Dr. J. A. Allan has found more than 40,000 feet (12,192 m.) of conformable sediments in the Rocky mountains. The still older strata of the Selkirks are nearly or quite as thick.

TABLE OF CORDILLERAN FORMATIONS.

System.	Formation.	Thickness.	
		Feet.	Metres.
Recent and Pleistocene.....	Fluviatile, lacustrine, glacial...............	....	....
	Unconformity.		
Oligocene (?)........	Kamloops volcanic group	3,000+	914+
	Tranquille beds (largely tuffs)................	1,000	305
	Unconformity.		
Eocene.............	Coldwater group (conglomerate, sandstone, etc.) of Interior......	5,000	1,524
	Puget group of Coast...	....	....
	Rhyolite porphyry at Ashcroft.............	....	....
	Unconformity		

TABLE OF CORDILLERAN FORMATIONS—*Continued.*

System.	Formation.	Thickness. Feet.	Thickness. Metres.
Lower Cretaceous (Comanchean)....	Jackass Mountain group and Queen Charlotte Islands group (sandstones, shales, conglomerates) of the west................	....	....
	Upper Ribboned sandstone................	550	168
	Kootenay Coal Measures ? Rocky Mts...........	2,800	853
	Lower Ribboned Sandstone................	1,000	305
	Spence's Bridge Volcanic group..............	....	....
Jurassic............	Fernie shale of Rocky Mts.................	1,500	457
	Upper part of Nicola group (Interior)......	....	....
Triassic............	Lower part of Nicola group (basic volcanics with limestone........	10,000∓	3,048∓
	Boston Bar group of Coast range (Triassic?)	....	....
Unconfor	*mity with Pennyslvanian.*		
Permian............	Upper Banff shale......	1,400	427
Pennsylvanian......	Rocky Mountain quartzite (thickness, 244m.) Upper Banff limestone (thickness, 701 m.)....	Rocky Mts.	
	Cache Creek group of the Western Belt (quartzite, limestone, basic volcanics)............	9,500	2,896

TABLE OF CORDILLERAN FORMATIONS—*Continued.*

System.	Formation.	Thickness.	
		Feet.	Metres.
Mississippian.......	Lower Banff shale......	1,200	366
	Lower Banff limestone (partly Devonian)....	1,500	457
Devonian...........	Intermediate limestone..	1,800	548
	Sawback limestone (Devonian?); (thickness, 1,128 m.)...........	....	....
Silurian............	Halysites beds..........	1,850	563
Ordovician..........	Graptolite shale........	1,700	518
	Goodsir shale...........	6,040	1,841
Upper Cambrian....	Ottertail limestone......	1,725	526
	Chancellor shales.......	4,500	1,372
	Sherbrooke limestones...	1,375	419
	Paget limestones........	360	110
	Bosworth limestones....	1,855	565
Middle Cambrian...	Eldon limestones........	2,728	831
	Stephen limestone-shale	640	196
	Cathedral limestones....	1,595	486
Lower Cambrian....	Mt. Whyte sandstone shale.... } Rocky Mts.	....	....
	St. Piran quartzite.......... } Rocky Mts.	....	....
	Lake Louise shale } Rocky Mts.	....	....
	Fairview sandstone......... } Rocky Mts.	....	....

TABLE OF CORDILLERAN FORMATIONS—*Concluded.*

System.	Formation.	Thickness.	
		Feet.	Metres.
	Sir Donald quartzite........... (Selkirk Mts.)	5,000	1,524
	Ross quartzite, upper part...... (Selkirk Mts.)	2,750	838
	Conformity in Selkirk Mts; local unconformity in Rocky Mts.		
Beltian............	Ross quartzite (lower part)................	2,500	762
	Nakimu limestone......	350	107
	Cougar quartzites.......	10,800	3,292
	Laurie metargillites.....	15,000	4,572
	Illecillewaet quartzite...	1,500	457
	Moose metargillite......	2,150	655
	Limestone.............	170	52
	Basal quartzite.........	280	85
	Unconformity.		
Pre-Beltian .... (Shuswap series)	Adams Lake greenstones	10,000	3,048
	Tshinakin limestone-metargillite..........	3,900	1,188
	Bastion schists (phyllites, etc.)................	6,500	1,981
	Sicamous limestone.....	3,200	975
	Salmon Arm mica schists.	1,800	548
	Chase quartzite.........	3,000	914
	Tonkawatla paragneiss (?)............	1,500	457
	Base concealed.		
	Total thickness (minimum)	135,018	41,150

The more important volcanic formations are listed in the table. A few subordinate bodies of lavas and pyroclastics, together with very numerous intrusive masses, will be noted in the sequel. Igneous activity is registered in the pre-Beltian, Beltian, Palæozoic, Mesozoic, and Cenozoic eras.

Shuswap Terrane.

Detailed work has been only begun on the widely exposed pre-Beltian rocks, which form the crystalline basement of British Columbia and share the complexity of the "Archean" in all parts of the world. They consist of a very thick, conformable, bedded group, called the Shuswap series, and a younger group of granitic intrusives. The whole complex may be conveniently named the *Shuswap terrane*.

Shuswap Series—Owing to structural difficulties, to the ruggedness of the mountains, and especially to a dense forest cover, it has not yet proved possible to construct a definitive columnar section for the Shuswap series. It is best exposed on the shore-lines of the Shuswap lakes and of Adams lake, during the low-water season of the year. However, one can seldom follow a contact or other structural plane far from the lake shore. Faults, thrust-planes, and folds are unusally difficult to map in this thoroughly metamorphosed mass of sediments and volcanics. Neither the top nor the bottom of the series has been found. The oldest sediments are interleaved with, and underlain by, intrusive granites, chiefly developed as sills. The youngest member on Adams lake where it is best exposed, is truncated by the present erosion surface.

Obscure as the structures generally are, it is quite clear that the Shuswap series is exceedingly thick. A provisional columnar section may be stated, as follows:

Tentative Columnar Section of the Shuswap Series.

	Thickness. Feet.	Metres.
Top, erosion surface.		
Adams Lake formation; greenstone schists.	10,000	3,048
Tshinakin formation:		
Limestone (1,500 ft., 457 m.)		
Phyllitic metargillite (800 ft., 244 m.)		
Limestone (1,600 ft., 488 m.)		
Total	3,900	1,188
Bastion schists, phyllite with green schists at top	6,500	1,981
Sicamous limestone	3,200	975
Salmon Arm schists, micaceous	1,800	547
Chase quartzite	3,000	914
Tonkawatla paragneiss	1,500+	457+
Base concealed		
	29,900	9,111

The *Tonkawatla formation* is exposed in a series of railway cuts 3 miles (5 km.) west of Revelstoke. It consists of a dark-coloured, massive, homogeneous, comparatively fine-grained gneiss bearing thin interbeds of white crystalline limestone. The latter are seldom over 2 inches (5 cm.) in thickness but are locally numerous. Their presence suggests that the whole group of rocks here exposed is of sedimentary origin. The gneiss is rich in biotite and plagioclase and is probably best interpreted as originally a calcareous argillite. The paragneiss passes upward into yet more massive, harder biotitic quartzite, which also carries thin intercalations of limestone.

Quartzite of identical habit and tentatively ascribed to the same horizon, is exposed on the slope due south of Shuswap station near the village of Chase. Here the thickness is to be measured in hundreds of metres and a special name, *Chase quartzite*, has been given to the member. Besides the thin beds of limestone, the quartzite often shows abundant disseminated grains of carbonate, largely calcite.

At Shuswap station the massive Chase quartzite is directly overlain by coarse, glittering muscovite-biotite schist, often garnetiferous and seamed with beds of micaceous quartzite. As usual in the Shuswap series, the planes

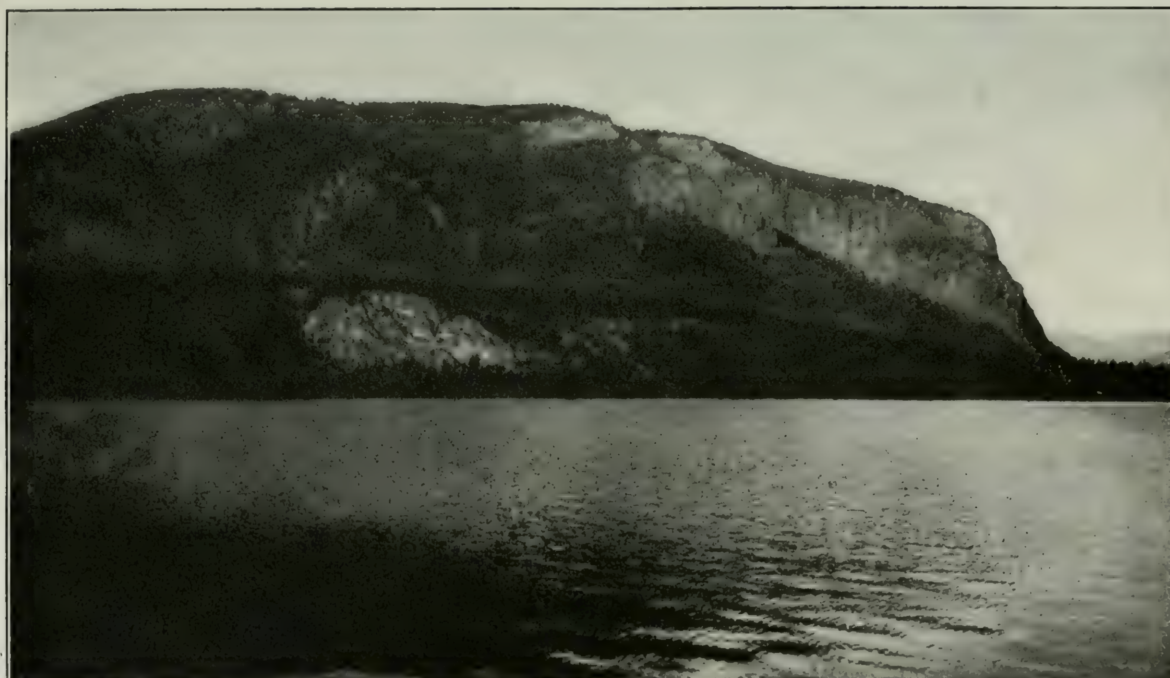
of bedding and schistosity are coincident. A thickness of some 1,500 feet (457 m.) is locally represented in these schists. They appear to be of the same horizon as a group of schists exposed in still greater strength on Salmon Arm of Shuswap lake; the name *Salmon Arm schist* may be given to the member. The coarse crystallization of the plainly sedimentary formation is due to the contact metamorphism of countless granitic sills and laccoliths. On the cliffy slopes at the eastern end of Bastion mountain the coarse schists pass up gradually into phyllite, a less metamorphosed phase.

On the slope just mentioned the Salmon Arm schists are conformably overlain by the thick *Sicamous limestone*, named for its occurrence at Sicamous station. This is a thin-platy, light bluish-gray to dark gray or almost black limestone, generally interrupted by closely spaced sericitic films. The range in colour tints is due to variation in the amount of carbonaceous matter disseminated through the limestone. The rock effervesces with cold dilute acid, but it is somewhat magnesian.

The western slope of Bastion mountain is in part underlain by the *Bastion schists* conformably overlying the Sicamous limestone These are best exposed on the shore of the lake, north of Canoe point opposite Sicamous. They are chiefly sedimentary phyllites but at the top are green schists, apparently of volcanic orgiin.

On Adams lake, schists like the last-mentioned rocks, are conformably overlain by the composite *Tshinakin formation*, which, in turn, is there conformably overlain by a gigantic series of greenstones and green schists, the *Adams Lake formation*, enclosing rare interbeds of limestone and phyllite. To this youngest recognized member of the Shuswap series Dawson gave the name "Adams Lake series", and he regarded it as of Cambrian date and of volcanic origin. More recent work has referred it to the Pre-Beltian series. Dawson estimated the thickness of these volcanics as 25,000 feet (7,620 m.); the apparent thickness is certainly greater than 10,000 feet (3,048 m.).

No complete field section has yet been found in the great Shuswap terrane and several of the horizons have been brought into the described relations through lithological similarities in different sections. That principle is of specially hazardous application in a region of complete metamorphism like that now under consideration. The



Bastion mountain from the west, showing the Sicamous limestone (in the high bluff) overlain by the Bastion schists (background, on the left). The large outcrop near the middle of the view is intrusive syenite.

table of formations will therefore surely need emendation. Nevertheless, it will serve to give a picture of the leading stratigraphic inferences so far made and to indicate in a qualitative way the magnitude and variety of the formations composing the Shuswap series.

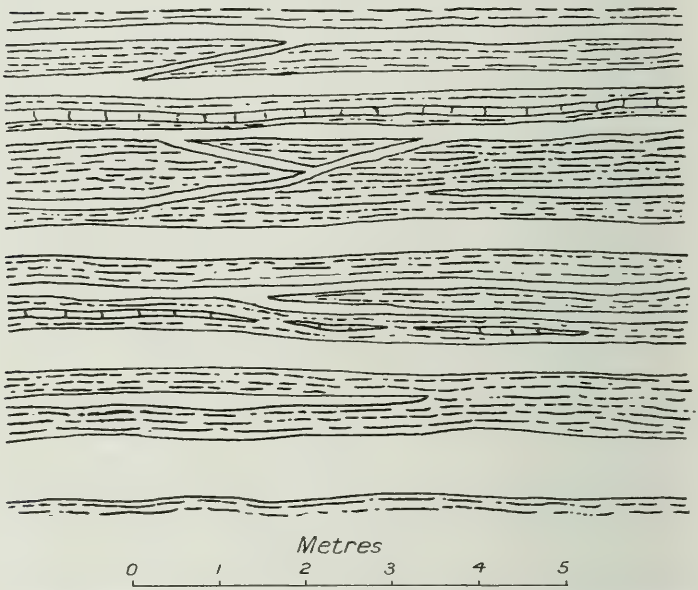


Diagram showing metasedimentary schists, thin limestone interbeds, and intrusive sills (left blank) of the Shuswap terrane, in typical relations; locality near Carlin siding.

Orthogneisses and Intrusive Granites.—Without exception each member of the Shuswap series has been intruded by granitic magma of pre-Beltian age. Some of the largest of these intrusive bodies are true cross-cutting batholiths which have developed strong metamorphic aureoles. However, most of the intrusions, literally innumerable, are not subjacent or bottomless but are to be classed with the 'injected' bodies. Sills are specially conspicuous. Some of the injections are thick and apparently of laccolithic form and mechanism; others have roofs and floors, but cross-cut the bedded formations and these may be described as chonoliths. Dykes are

Aplitic and pegmatitic sills cutting rusty metasedimentary schists and limestone interbeds; Shuswap terrane, western shore of Mara Arm of Shuswap lake.

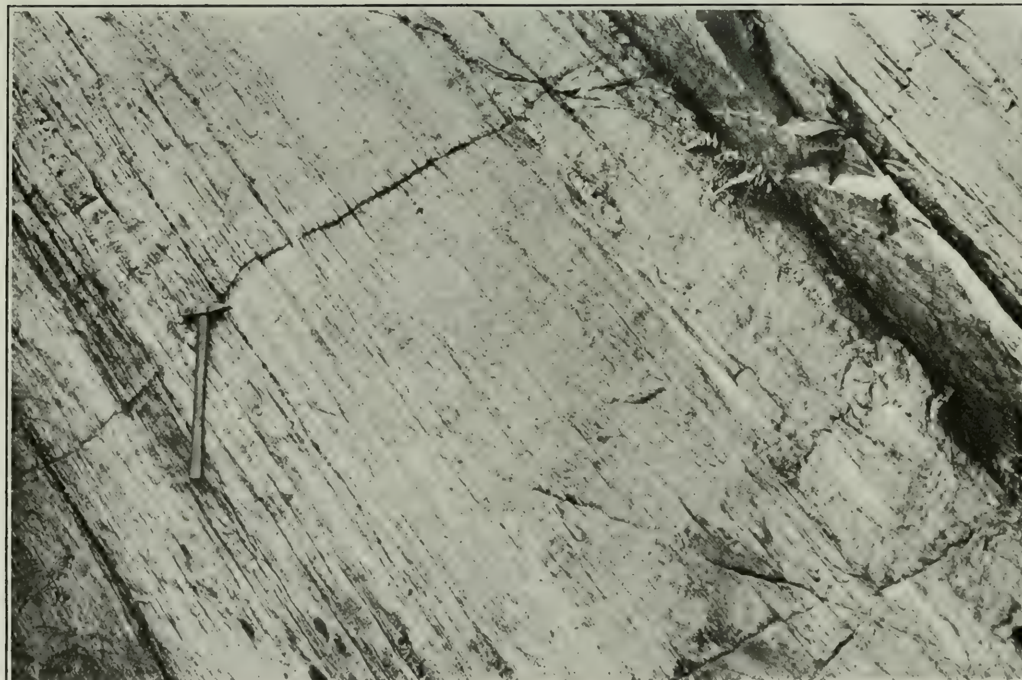
very numerous, in part representing the feeding channels for the other types of injection.

The injected bodies are, in part, clearly satellites of underlying batholiths, but it is possible that many of them are due to the migration of hydrous magmas locally generated in the depths of a greatly metamorphosed terrane.

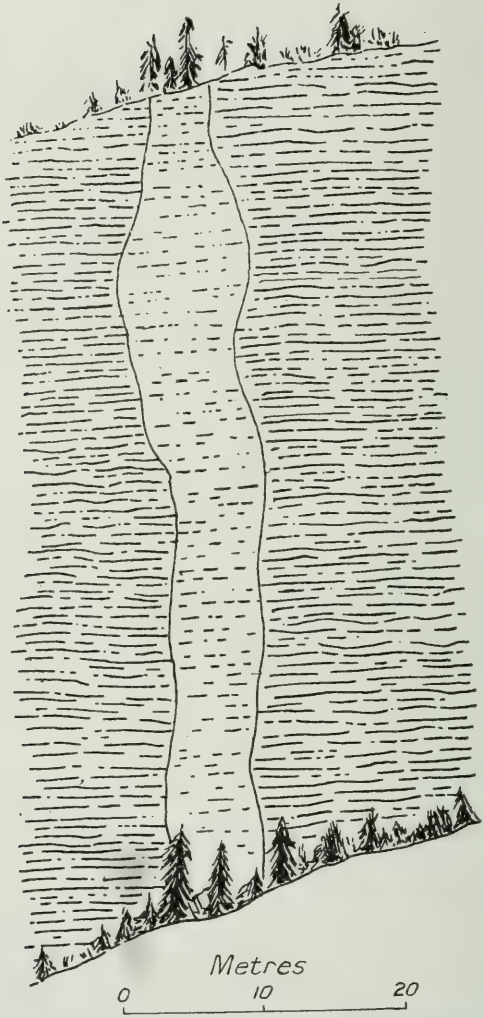
The principal petrographic types in these intrusions are: biotite granite (most abundant); hornblende-biotite granite; two-mica granite (rare); pegmatite and aplite (both very abundant); and orthogneisses corresponding to each of these magmatic species. Extended microscopic study shows that there is little mineralogical novelty; the rock types are duplicated in most of the 'Archean' tracts on the globe and are usually gneissic in structure.

The extraordinary prevalence of sills and other concordant injections is explained by the extreme fissility of the Shuswap sediments and greenstones. This feature is due to static metamorphism. As shown in the following section on structure, the dips of the Shuswap terrane are generally low. Though its rocks have passed through several periods of energetic mountain-building, their dips over large areas do not surpass 15° and their average dip is probably no greater than 35°. The metamorphism is essentially as far advanced where the strata lie horizontal as where they are dipping at angles of 60° to 90°.

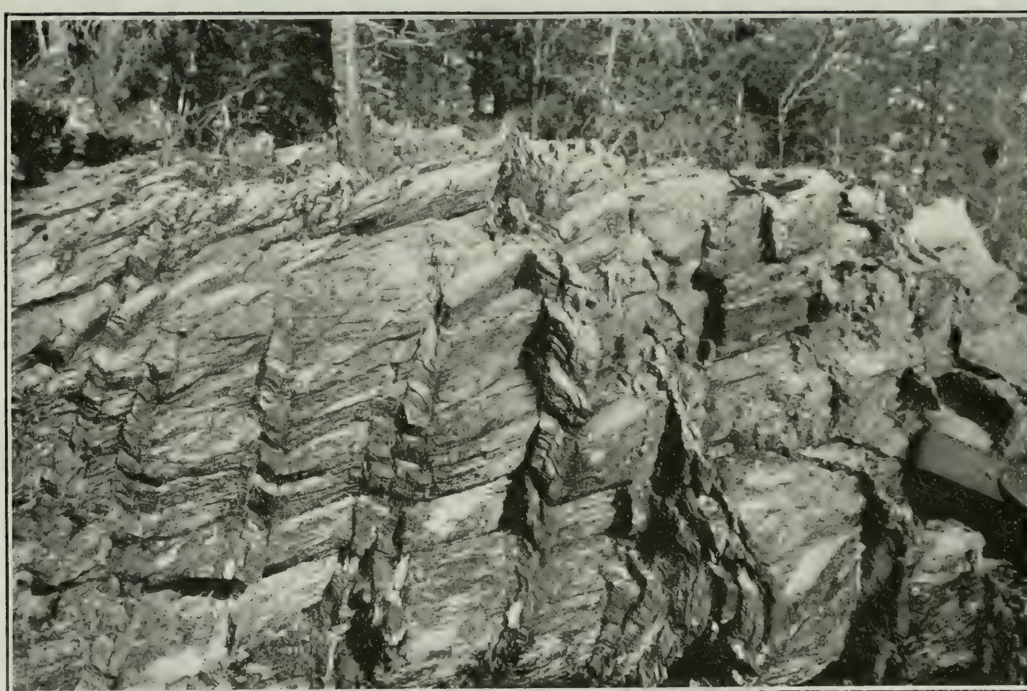
Further, it seems highly probable that the fissility had attained nearly its present perfection before the Beltian system of rocks was deposited in the Shuswap terrane, and thus at an early date in the earth's history. The conditions for the metamorphism include: deep burial, with consequent development of "stress" in the vertical direction; and an abundant supply of interstitial water, such as that originally trapped in the sediments and volcanic beds. The completeness of recrystallization, which is much more striking than that visible in similar geosynclinal rocks of Cambrian or later date, implies that at least one other condition was here necessary. Hypothetically we may find it in a specially steep thermal gradient, controlling subsurface temperatures in pre-Beltian times. Field evidence thus leads to the suspicion that the earth was then notably hotter than it was later, when most of the known thick masses of sediments were deposited.



Schistose structure of typical orthogneiss in Shuswap terrane, illustrating static metamorphism. The hammer is about 32 cm. in length. Locality, Albert Canyon station.



Cliff section of aplitic dyke cutting paragneiss(?); Shuswap terrane at Clanwilliam. The dyke shows nearly horizontal schistosity, parallel to that in its country rocks; all have undergone static metamorphism since the intrusion of the dyke.



Strain-slip cleavage in talc schist of the Shuswap series, at Blind bay. The well developed low-dipping schistosity is due to earlier static metamorphism. Camera case about 7 cm. thick.

Whatever be the explanation, it is clear that the Shuswap series has not been seriously affected by dynamic metamorphism. The strata and most of the injected granites were completely or almost completely recrystallized while the strata lay nearly flat. In some localities the effects of dynamic metamorphism have been superposed on those due to previous static metamorphism. An example is illustrated on page 131. Similarly, thermal metamorphism produced by sills or batholiths is generally easy to distinguish from the prevailing regional type. Contact action has either coarsened the grain of the invaded formation or has developed hornfelses bearing minerals characteristic of plutonic contacts. The older members of the Shuswap series are, in general, more coarsely crystalline than the younger, partly because of deeper burial, but more because of the greater abundance of intrusions at the lower horizons.

BELTIAN SYSTEM.

Unconformably overlying the Shuswap terrane in the Selkirk mountains is a vast thickness of conformable, unfossiliferous sediments, for which as a whole the name, *Selkirk series*, has been adopted. The lower and greater portion of these beds is of pre-Cambrian age; the uppermost beds, as exposed in the railway section are referred, on stratigraphic evidence, to the Lower Cambrian. The group is clearly the northern continuation of the Belt series of Montana and Idaho. To the Pre-Cambrian portion of each series Walcott has applied the name 'Beltian' as a systemic designation and it will be adopted for present use.

In the railway section the Beltian is constituted of the following members.:

Columnar Section of the Beltian System in the Selkirk Mountains.

		Approximate Thickness.	
		Feet.	Metres.
	Top, erosion surface.		
Glacier Division (*Selkirk series of Dawson*).	Ross quartzite (in part)....	2,500	762
	Nakimu limestone........	350	107
	Cougar formation (quartzite with metargillitic beds)	10,800	3,292
Albert Canyon Division (*Nisconlith series of Dawson*).	Laurie formation (metargillite, often calcareous; with subordinate interbeds of limestone and quartzite; basal bed, gray limestone 15 m. thick)..	15,000	4,572
	Illecillewaet quartzite......	1,500	457
	Moose metargillite........	2,150	655
	Limestone (marble).......	170	52
	Basal quartzite...........	280	85
Base, unconformity with Shuswap terrane.			
		32,750	9,982

In the railway section the *basal quartzite* is a greenish-gray, fine-grained metarkose, a massive to well-bedded, feldspathic rock of quartzitic habit, though strongly charged with films of sericitic mica. The original material was the somewhat washed sand due to the secular decomposition of the underlying Shuswap orthognesis. It will be described in greater detail in a following account of the geology about Albert Canyon station.

At its top the quartzite is interleaved with the lowest layers of the overlying *limestone*. This is a thin-bedded to thick-bedded, white to bluish marble, generally weathering to a pale buff colour. It is magnesian throughout, though some beds are more purely calcitic than others.

The *Moose metargillite* has been so designated from an older name of Albert creek, which enters the Illecillewaet river at Albert Canyon station. The middle part of this formation has not yet been found in satisfactory exposure

but the whole seems to be a fairly homogeneous argillite, now largely recrystallized by static metamorphism—a metargillite. All phases are charged with sericite, developed parallel to the bedding planes, and occasionally one finds thin beds glittering with coarser mica like a normal muscovite schist. The colour is generally gray, of a dark tint due to disseminated particles of carbon.

The *Illecillewaet quartzite* is hard, gray, massive to fissile, and relatively homogeneous except for thin intercalations of metargillite. Unlike the basal quartzite, it is poor in feldspathic material and evidently represents a more completely washed and assorted sediment.

In the monoclinal section between Albert Canyon and Ross Peak stations, the *Laurie formation* (named after the mining camp at the railway) is of most remarkable thickness. Measurement on the actual outcrops gave the following succession.

	Approximate Thickness.	
	Feet.	Metres.
Base of the Cougar formation.		
Gray, phyllitic metargillite	4,000	1,219
Quartzite	650	198
Black to dark gray metargillite	500	152
Alternating beds of phyllite and quartzite	750	229
Black to dark gray, carbonaceous, often pyritous metargillite, with interbeds of blackish limestone	9,300	2,835
Gray quartzite	400	122
Black to dark gray, strongly carbonaceous metargillite, with numerous interbeds of blackish limestone	3,500	1,067
Massive, light gray limestone	50	15
Top of Illecillewaet quartzite.		
	19,150	5,837

There is no sign of important duplication by strike-faulting, though some thickening is represented in local crumples. Admitting all possible duplication suggested by the facts now in hand, this formation must be credited with a thickness of more than 15,000 feet (4,572 m.). On

Top of Cougar mountain, looking southeast; showing Cougar quartzite as typically developed in the Selkirk range.

account of the general uniformity of composition and habit, no satisfactory subdivision of the formation is yet feasible; because of their limited exposure in the railway zone, the quartzitic beds cannot be used for subdivision.

The *Albert Canyon division* of the Selkirk series is thus chiefly of metargillitic composition. The overlying *Glacier division*, more especially as it crops out on the western slope of the Selkirk range, is dominantly quartzitic.

Its most heterogeneous member is the *Cougar formation*, named from Cougar mountain, in which it is exposed on a great scale. In the monocline between Caribou creek and the Caves of Cheops (Nakimu), the formation shows the following general succession.

Columnar Section of the Cougar Formation.

	Thickness.	
	Feet.	Metres.
Conformable base of the Nakimu limestone.		
Gray, thin-bedded to thick-bedded quartzite, weathering rusty; with thin interbeds of phyllite and white quartzite; a few seamlets of crystalline limestone in the uppermost quartzite..........	5,500	1,677
Conspicuous band of white, homogeneous, massive quartzite..........	300	91
Massive, light gray quartzite, interrupted by many bands of gray, quartzitic grit and coarse sandstone and by beds of dark gray, silicious metargillite; about 1,000 feet (305 m.) from the top, a thick band of massive white quartzite..........	3,000	915
Quartzitic and phyllitic, gray sandstone and fine conglomerate with metargillite. Near the middle of this zone, angular fragments of altered basaltic rock (bombs?) enclosed in an argillaceous (?)base were found..........	900	274
Altered basaltic lava..........	50	15
Thick-platy to flaggy, sometimes phyllitic, gray quartzite..........	1,050	320
Conformable top of Laurie formation.		
	10,800	3,292

East of the divide of the Selkirk range, the Cougar formation is, on the whole, thin-bedded and more argillaceous (originally) than in the section just detailed. The equivalent strata of the Rocky mountains—the Corral Creek formation and the lower part of the Hector formation —are still more argillaceous, consisting of gray, green, purple, and black metargillites with interbeds of rusty quartzite. (See p. 172). The rocks of this general horizon thus become finer-grained, less purely silicious, and more argillaceous as the section is followed from west to east. A similar variation characterizes the Rocky Mountain Geosynclinal rocks at the 49th Parallel section.

The *Nakimu limestone* is specially notable as being the most useful horizon-marker in the Selkirk and Purcell mountains. It is truly protean in lithological features, but one is seldom at fault in identifying it in the field. The Caves of Cheops (Caves of Nakimu) have been formed by solution and by the mechanical erosion of Cougar creek, as it follows for some distance a subterranean course in the formation. At that, most westerly, outcrop the formation is a light gray, fine-grained crystalline limestone. The rock is comparatively homogeneous, but carries disseminated sericitic mica in many beds. In the outcrops of the eastern Selkirks and of the Purcell mountains, the same gray type of limestone is interbedded with blackish, very carbonaceous limestone and with rusty-weathering, sandy or pebbly, dolomitic limestone. The thickness is quite variable—from as much as perhaps 600 feet (183 m.) at the Caves of Cheops to a few feet near Beavermouth. These differences are in part original; in part they seem to be due to squeezing-out during the uplift of the mountains.

The Nakimu limestone is conformably overlain by the thick *Ross quartzite* named from Ross peak, a mountain opposite Cougar creek at its confluence with the Illecillewaet river. The lower part of this formation is of Pre-Cambrian age; the upper part is probably to be assigned to the Lower Cambrian. All these admirably exposed beds are conformable not only with one another but also with the definitely Lower Cambrian Sir Donald quartzite above.

In the section between the Caves of Cheops and Rogers Pass station near the summit of the Selkirks, the Ross formation is relatively homogeneous, with composition as here indicated:

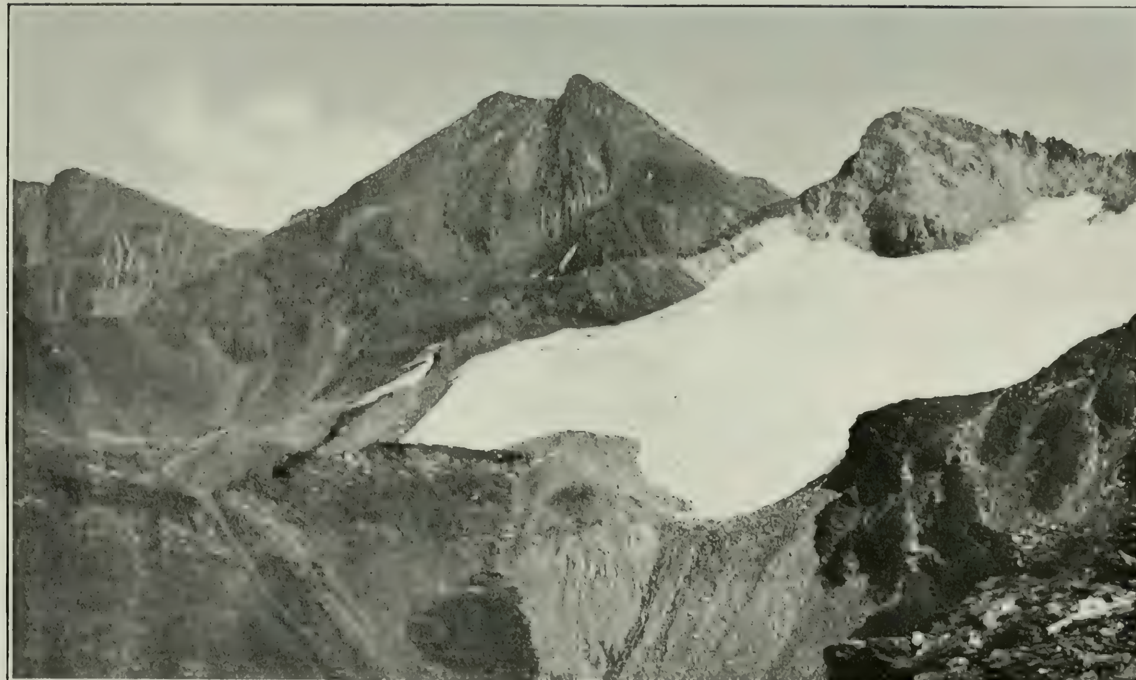
Columnar Section of the Ross Formation

	Thickness.	
	Feet.	Metres.
Conformable base of Sir Donald quartzite.		
Gray, rarely rusty, thick-bedded, compact quartzite, with interbeds of gray and brownish quartzitic sandstone and grit..........	1,200	366
Pale rusty-brown silicious phyllite or sericitic quartzite, carrying in the middle a 15-metre bed of gray quartzite....................	350	107
Gray quartzite, thick-platy and homogeneous, weathering gray and rusty; with interbeds of hard quartzitic grit and sandstone......	3,700	1,127
Conformable top of the Nakimu limestone.	5,250	1,600

In the grand exposures along the northwestern edge of Beaver River valley the Ross formation weathers more uniformly rusty but is still quartzitic; this section shows an approximate thickness of 5,000 feet (1,524 m.). At the summit of the Dogtooth mountains, the formation is more argillaceous, while retaining its deep rusty colour and numerous bands of fine quartz conglomerate or grit so characteristic in the Selkirks. It is correlated with the shaly to sandy beds in the upper part of the Beltian-Hector formation and in the Lower Cambrian Fairview formation —both exposed in the Bow River valley of the Rocky mountains. Here again the geosynclinal rocks in the east are more argillaceous than those contemporaneously deposited in the west.

Cambrian System.

At the summit of the Selkirk range the Ross quartzite passes gradually upwards into the *Sir Donald formation.* This is a very homogeneous mass of quartzite, much like



Summit of the Dogtooth range, looking east from a peak near head of Quartz creek. Slopes underlain by the Ross formation as typically developed in the Purcell mountains.

the more silicious phase of the Ross but weathering with a gray, rather than a rusty, surface. On fresh fractures the Sir Donald quartzite varies in the colour from white through pale gray and greenish-gray to dark gray, rarely rusty. It is characteristically thick-bedded. Like the Ross formation it is often feldspathic and is charged with numerous lenses of quartz-feldspar grit and fine quartz-feldspar conglomerate. Near the base there is a 53-metre band of pale-rusty to gray quartz-sericite schist.

Summit of Mt. Tupper from Tupper Crest, showing characteristic habit of the Sir Donald quartzite. Photograph by Howard Palmer.

The Sir Donald quartzite forms most of the highest summits of the Selkirk mountains and is terminated above by the present erosion surface. It has yielded no fossils but clearly represents the fossiliferous Lake Louise and St. Piran series of the Rocky mountains. The Lower Cambrian Mt. Whyte formation of the Rockies may also be correlated, tentatively, with the upper beds of the Sir Donald quartzite.

The general correlation of formations in the Selkirks and Rockies may be stated as follows:

	SELKIRK MOUNTAINS.	Thickness. Feet.	Thickness. Metres.	ROCKY MOUNTAINS.	Thickness. Feet.	Thickness. Metres.
	Erosion surface.			*Conformable base of the Middle Cambrian.*		
Lower Cambrian	Sir Donald quartzite	5,000+	1,524+	Mt. Whyte formation	390	119
				St. Piran formation	2,705	823
				Lake Louise formation	105	32
	Ross quartzite (upper part)	2,750	838	Fairview formation	600	183
Beltian	Ross quartzite (lower part)	2,500	762	Hector formation (upper part)	630	192
	Nakimu limestone	350+	107+			
	Cougar formation (in part)	10,800	3,292	Hector formation (lower part)	3,960	1,206
				Corral Creek formation	1,320	403
				Base concealed.		

With the exception of the Sir Donald and upper-Ross quartzites, Cambrian strata are absent in the railway section west of the Rocky Mountain trench. The enormous development of the Cambrian in the Rocky mountains was demonstrated by McConnell and Dawson. More recent studies by Walcott and Allan have led to its detailed subdivision, as here summarized.

Columnar Section of the Rocky Mountain Cambrian.

	Formation.	Thickness.	
		Feet.	Metres.
Upper Cambrian	Ottertail limestones.	1,725	526
	Chancellor shales, etc.........	4,500	1,372
	Sherbrooke limestones........	1,375	419
	Paget limestones.............	360	110
	Bosworth limestones, etc......	1,855	565
Middle Cambrian	Eldon limestones............	2,728	831
	Stephen limestones, etc.......	640	196
	Cathedral limestones.........	1,595	486
Lower Cambrian	Mt. Whyte shale, etc.........	390	119
	St. Piran quartzitic sandstone	2,705	824
	Lake Louise shale............	105	32
	Fairview sandstone, grit, etc..	600	183
		18,578	5,663

On pages 174ff. will be found Dr. Allan's summary description of these formations.

Ordovician System.

Ordovician strata are represented at the railway section only within the limits of the Rocky mountains and the floor of the Rocky Mountain trench. These beds once extended over the site of the Purcell range and over much

of the eastern Selkirks but have there been completely denuded. It is highly probale that the western half of the Cordillera was a land surface during the Ordovician.

In our section the system is composed of the *Goodsir shales* and the *Graptolite shales.* Dr. Allan credits them with respective thicknesses of 6,040 feet (1,841 m.) and 1,700 feet (518 m.). His account of them appears on pages 179-181.

Silurian System.

The Silurian rocks of the section seem to have had the same general distribution as the Ordovician shales. To the younger system belong the *Halysites beds*, a formation named by McConnell and described on page 181 by Dr. Allan, who estimates the thickness of the formation at 1,850 feet (563 m.)

Devonian System.

Sediments of Devonian age in the railway section are also confined to the Rocky mountains. The *Intermediate limestone*, named by McConnell and described by Dr. Allan on page 181 has a thickness estimated at 1,800 feet (548 m.) or more. In the Sawback range it is conformably underlain by the unfossiliferous *Sawback formation*, 3,700 feet (1,128 m.) thick. This is certainly post-Cambrian but its exact age cannot now be declared. (See page 182.)

Mississippian System.

The strata formerly mapped as Carboniferous in the Rocky mountains of our section have recently been shown by Shimer to be partly Mississippian and partly Pennsylvanian in age.* The former system is represented in the *Lower Banff limestone* (thickness, 1,500 feet or 457 m.) and the overlying *Lower Banff shale* (thickness, 1,200 feet or 366 m.), both named in McConnell's original report. [**2**, p. 17]. Some details concerning these will be found on page 182.

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*H. W. Shimer, Summary Report, Geo. Surv. Can. 1910, p. 147. Since this passage was written Dr. Shimer has concluded from palaeontological evidence that at least part of the Lower Banff limestone is Devonian.

Pennsylvanian System.

In the Rocky mountains of our section the Pennsylvanian system includes the *Upper Banff limestone*, and the overlying *Rocky Mountain quartzite*, with estimated or measured thicknesses of 2,300 feet (701 m.) and 800 feet (244 m.) respectively. Dr. Allan's account of them is given on page 183.

Pennsylvanian rocks show yet greater thickness in the western half of the Cordillera, where they represent the the oldest Paleozoic strata known in the railway section. They have been named by Dawson the *Cache Creek group*, his own description may be quoted in abstract. Writing of the group as a whole he says:

"The lower division consists of argillites, generally as slates or schists, cherty quartzites or hornstones, volcanic materials with serpentine and interstratified limestones. The volcanic materials are most abundant in the upper part of this division, largely constituting it. The minimum volume of the strata of this division is about 6,500 feet. The upper division, or Marble Canyon limestones, consists almost entirely of massive limestones, but with occasional intercalations of rocks similar to those characterizing the lower part. Its volume is about 3,000 feet.

"The total thickness of the group in this region would therefore be about 9,500 feet, and this is regarded as a minimum. The argillites are generally dark, often black, and the so-called cherty quartzites are probably often silicified argillites. The volcanic members are usually much decomposed diabases or diabase-porphyrites, both effusive and fragmental, and have frequently been rendered more or less schistose by pressure . . . .

"In the southern part of British Columbia, the Cache Creek group shows some evidences of littoral conditions toward the west slopes of the Gold [Columbia and adjacent] ranges, probably indicating the existence of land areas there." [**5**, p. 70].

Travelling westward over the railway, the Cache Creek rocks first appear in a long section east of Kamloops on the South Thompson river. (See page 231). The group originally covered all, or almost all, of the western half of the Cordillera and has been found to have a thickness of at least 6,800 feet (2,073 m.) in the Chilliwack canyon, near Vancouver. [**11**, Part I, p. 514, and Part II, p. 559].

Dr. N. L. Bowen's Agassiz series, noted on page 258, is probably part of the same great geosynclinal.

Permian System.

As yet rocks of Permian age are known only in the Rocky Mountain portion of the railway section. There Shimer has shown that the *Upper Banff shale* is to be so dated. With a thickness of 1,400 feet (427 m.) it lies conformably upon the Rocky Mountin quartzite. Dr. Allan summarizes the character of the formation on page 183.

Triassic System.

No formations referable to the Triassic are known in the railway section across the Rocky, Purcell, Selkirk, and Columbia Mountain ranges. On the other hand, Triassic rocks are extensively developed in the western half of the Cordillera, where they have had a volume comparable to that of the Cache Creek phase of the Pennsylvanian. Dawson proved the lower Mesozoic age of his *Nicola group*, which still covers large areas in the Belt of Interior Plateaus. The greater part of this group is constituted of basic volcanic rocks (chiefly basalts and diabases) with thin interbeds of limestone carrying Triassic fossils. The upper members of the group are referred to the lower Jurassic. Dawson estimated the total thickness at the Thompson river to be 13,500 feet (4,115 m.), of which at least nine-tenths represents volcanic rock. On account of the extraordinary massiveness of the lavas, it has as yet proved impossible to make a trustworthy columnar section for the group.

Thick fossiliferous shales of Triassic age have been found in the Cascade range just south of the railway at Harrison Mills, 61 miles (98 km.) from Vancouver. The Boston Bar argillites, occurring between Lytton and Hope, have recently been shown by Dr. Bowen to be of Mesozoic age and may also belong to the Triassic.

Jurassic System.

Excepting those noted in the Nicola group, no Jurassic fossils have been discovered in our section west of the

Characteristic outcrop of Triassic (Nicola) basalts near Ducks station. The terrace is composed of the white Thompson River silts.

Rocky mountains. In that range itself the rock system is represented by the *Fernie shale*, with a thickness of 1,500 feet (457 m.). Its description is briefly given by Dr. Allan on page 184.

Cretaceous System.

Following the orogenic disturbances near the close of the Jurassic, sedimentation in our section became restricted to relatively narrow geosynclines or zones of overlap. A thick mass of Cretaceous strata was deposited in a downwarp along the eastern limit of the Cordilleran area. Other local geosynclinal prisms were developed near the line of the present Pacific coast. The stratigraphy of each of these two sedimentary provinces needs separate treatment.

In the eastern Rockies, west of Bankhead, beds lying conformably on the Jurassic Fernie shale and all of Lower Cretaceous age, have been subdivided into three formations: the *Lower Ribboned sandstone*, the *Kootenay Coal measures* and the *Upper Ribboned sandstone*. Their respective thicknesses are approximately: 1,000 feet (305 m.), 2,800 feet (853 m.), and 550 feet (168 m.). On page 185 is to be found Dr. Allan's description of the formations. The railway section does not give the full thickness of this geosynclinal, to which Dawson has credited a value of more than 11,000 feet (3,353 m.).

Six hundred kilometres (370 miles) farther west, Lower Cretaceous rocks again appear in the section. They cover two principal areas: one at Ashcroft, the other following the Fraser valley north and south of Lytton. Both groups of rocks are doubtless remnants of a single geosynclinal, once covering part of the Belt of Interior Plateaus as well as part of the Coast Range region. A still greater remnant has been mapped at the 49th parallel section under the name Pasayten series, of which the Lower Cretaceous members alone have a thickness of about 7,000 metres.

The erosion remnants at Ashcroft and Lytton consist of highly indurated sandstones, argillites and conglomerates. "The sandstones are most commonly of greenish-grey colours, passing on one hand into coarse, distinctly green rocks, largely composed of arkose materials derived from the older [Paleozoic and Triassic] greenstones and [late Jurassic] granites; on the other, into fine-grained blackish sandstones, which grade down perceptibly into argillites

of the same colour." [**4**, p. 151]. Owing to structural complication, no attempt at a detailed section of the Cretaceous in either of the areas has yet been successful. Dr. Drysdale estimates the minimum thickness of the Ashcroft remnant at 5,000 feet (1,524 m.), while Dawson indicated a value of 7,000 feet to 10,000+feet (2,133 to 3,048+m.) for the Fraser valley Cretaceous. A partial section in the latter area (Jackass Mountain series) is given by Dr. Bowen on page 258. Mr. Camsell also refers certain quartz porphyry flows found west of Hope station to the Lower Cretaceous. (See page 273.)

EOCENE SYSTEM.

In our section rocks of Tertiary age are entirely confined to the western half of the Cordillera. So far as known, they have originated in volcanic action or in fresh-water sedimentation, though it is possible that the Eocene strata of the Pacific coast are partly marine.

The formations assigned to the Eocene are: the sedimentary *Coldwater group*; and the sedimentary *Puget group*. These are local formations and their mutual relations have not been fully determined.

The Coldwater group, named and mapped by Dawson, is probably younger and includes conglomerate, sandstone, shale and coal accumulated in the valleys formed during and after post-Cretaceous mountain-building. Penhallow's recent study of the fossil floras contained in these beds as mapped by Dawson refers at least part of them to the Eocene proper [**6**, p. 106]. Dawson estimated the local maximum thickness of the Coldwater beds to be about 5,000 feet (1,524 m.)

Like the other Eocene groups, the Puget beds—sandstones, conglomerates and shales with thin coal beds—are in unconformable relation to the Cretaceous. They attain very great thickness in Puget sound. In the railway section the group is truncated by the existing erosion surface; the remnant of the Tertiary sediments on the lower Fraser has an observed thickness of about 3,000 feet (914 m.)

OLIGOCENE SYSTEM.

The Belt of Interior Plateaus is widely covered with lavas mapped by Dawson as the 'Upper Volcanic Group'

and referred by him to the Miocene, as then defined for western stratigraphy [**5**, p. 80]. Dr. Drysdale is still inclined to regard the lavas as of lower Miocene age (see page 243), though recent paleontological and stratigraphical work by Lambe and Penhallow seems to show that these rocks—hereafter called the *Kamloops Volcanic group*—should be assigned to the Oligocene. The fossils in question, fish remains and plants, have been found in the *Tranquille beds*, a series of local, tuffaceous, partly fresh-water sediments intercalated near the base of the Kamloops volcanics.

The Tranquille beds are estimated to have a thickness of 1,000 feet (305 m.); the Kamloops lavas, a maximum thickness of at least 3,000 feet (914 m.), with an original average thickness probably greater than 2,000 feet (610 m.)

The Kamloops volcanics are the youngest bed-rocks known in the railway section. Up to the present time no Miocene or Pliocene sediments have been found there. Within sight of the railway, at Mission Junction, is the Pleistocene-Recent volcano, Mt. Baker.

PLEISTOCENE SYSTEM.

The Quaternary formations are briefly noted at various appropriate places in this guide-book.

GENERAL STRUCTURE.

The sedimentary rocks of our trans-montane section belong to three geological provinces.

The Beltian and Lower Cambrian strata of the Selkirk mountains and their equivalents in the Rocky mountains, with the conformable formations of Middle Cambrian to Permian age, together form a single mass of rocks. In the Selkirks there is perfect conformity between the Lower Cambrian and Beltian systems ; in the Rockies their relation is reported to be that of conformity at some contacts, and that of moderate unconformity at others. (See page 172). There is no thorough-going unconformity in this gigantic series. It is, in fact, best regarded as a single geosynclinal prism of the first order. The maximum thickness of strata here represented is, perhaps, greater than that of any other measured group of sediments. With varying

strength and complication, including the presence of local unconformities, this prism is already known to extend from Colorado to Western Alaska. Throughout the length of the Cordillera in Canada and Alaska as well as in the United States proper, the Rocky mountains are almost wholly composed of the prism; hence this gigantic unit has been named the *Rocky Mountain Geosynclinal*. On its back have been deposited, unconformably, local geosynclinals of late-Mesozoic and of early Tertiary dates. These have major axes parallel to that of the older, greater prism and parallel to the general axis of the Cordillera. The whole, compound assemblage of sediments forms the *Eastern Geosynclinal Belt* of the Cordillera.

On the other hand, the chief sedimentary rocks of the Coastal system of mountains—including the Coast range of Alaska and British Columbia, the Vancouver range, the Olympic mountains, the Cascade range, and the Sierra Nevada of California—are of Carboniferous (Pennsylvanian), Triassic, and Jurassic age. These beds were deposited in a broad, very long zone of subsidence. The sedimentation was not continuous; there are local unconformities in the series. Yet, as a whole, this deposition was long-continued and on a regional scale within the geographical zone described. Since, moreover, the clastic strata were deposited in Pacific water and represent detritus largely from the Eastern Belt, the whole complex prism may be called the *Main Pacific Geosynclinal*. After a late-Jurassic orogenic revolution affecting this entire prism, local areas of the now deformed zone were downwarped and received heavy loads of sediment in the form of Cretaceous and early Tertiary geosynclinal prisms. These, along with the much greater Main Pacific Geosynclinal, form the *Western Geosynclinal Belt* of the Cordillera.

Between the two belts, on the line of the Canadian Pacific Railway, lies the *Shuswap Terrane*, the third and last of the major sedimentary provinces. Its rocks are of Pre-Cambrian (pre-Beltian) age. In our section, the eastern limit of the terrane is at Albert Canyon on the western slope of the Selkirks; its western limit is a few miles below the outlet of Little Shuswap lake, in the Belt of Interior Plateaus.

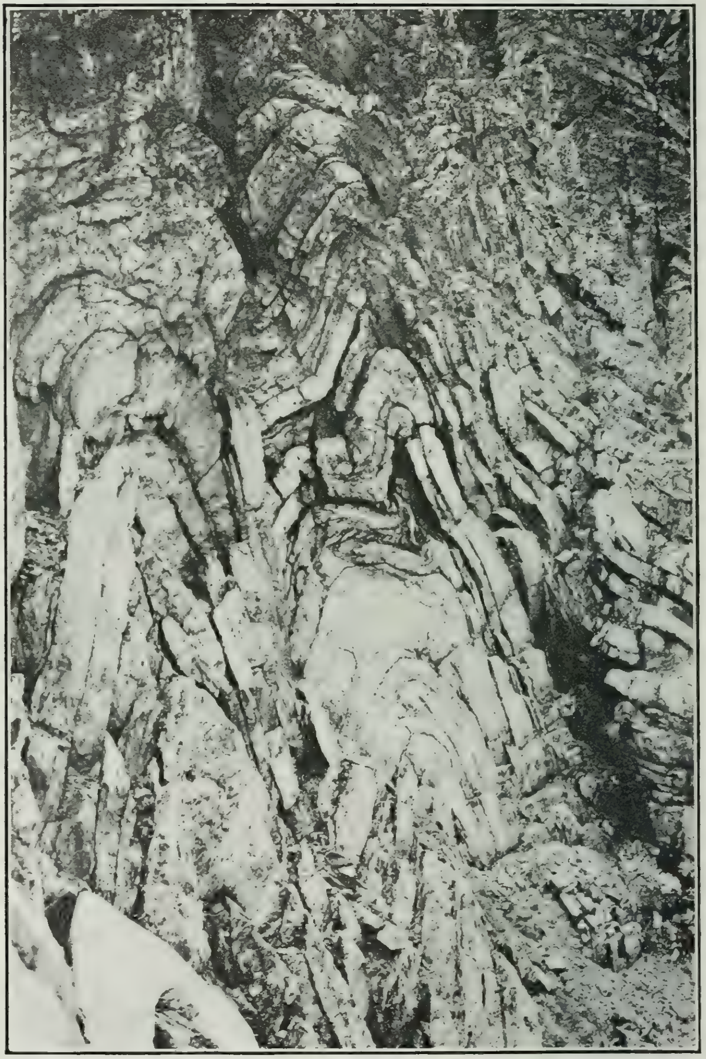
Along the railway, the Rocky mountains form a synclinorium, broken by numerous faults and by occasional zones of mashing. The eastern limb of the synclinorium

is thrust at least 11 kilometres (7 miles) over somewhat deformed Cretaceous strata. The western limb terminates in a master-fault running in the general line of the Rocky Mountain trench. This fault, with downthrow of at least 5 kilometres (3 miles), is likewise the eastern limit of a second synclinorium forming the Purcell mountains and the eastern part of the Selkirks. The western limit of this

Looking south from Mt. Tupper to Mt. MacDonald and Mt. Sir Donald (background), showing part of the summit syncline of the Selkirks as shown in the Sir Donald quartzite forming the great escarpment. Photograph by Howard Palmer.

broad flexure is a relatively simple monocline extending from the summit of the Selkirks to the primary unconformity at Albert Canyon.

Each synclinorium is unsymmetric, with older strata exposed on the western edge than on the eastern. This is particularly striking in the Selkirks, where the Shuswap terrane is exposed on the west, below the basal beds of the Beltian system, while the Cambrian quartzites appear at the surface not far west of the fault in the Rocky Mountain trench. The maximum amount of uplift registered in the railway section has charactertized the eastern part of the



Drag folds in the Cougar quartzite near head of Cougar creek, Selkirk range.
Cliff shown is about 15 m. in height.

Shuswap terrane, where the younger sediments of pre-Beltian age have been eroded away.

While the Shuswap sediments attained the thickness of a first-class geosynclinal, no clear hint has been forthcoming as to the geographical source of their clastic material, nor as to the direction of the major axis of this prism. There is nothing to show that the subsiding trough had the Cordilleran elongation which has been so characteristic of the post-Shuswap geosynclines. In two leading respects the pre-Beltian terrane contrasts structurally with the younger geosynclinals.

The Shuswap series is less deformed than any of the overlying series, up to and including the Triassic. In the Selkirks and Interior Plateaus the average dip calculated for the beds of the oldest terrane is no greater than 35°, while the averages for large, typical areas of the Albert Canyon division and Glacier division of the Selkirk series, for the Carboniferous, and for the Nicola series, are, respectively, about 38°, 59°, 73°, and 64°. This is true, though the Shuswap terrane obviously underlay these younger formations when they were passing through several orogenic revolutions. Today, the Shuswap rocks in numerous areas each many square miles in extent are nearly horizontal, while adjacent Carboniferous strata are intensely folded. It appears necessary to believe that the earth-shell which has here transmitted the mountain-building thrust had a depth of only a few kilometres; and that this shell was sheared over its basement of Shuswap rocks.

The second noteworthy feature is the general failure of the Shuswap strata to show the Cordilleran trend characteristic of all the younger formations. The prevailing strike of the basement rocks is about N. 70° E., and thus nearly at right angles to the general Cordilleran strike in this latitude. Quite locally the older rocks have been gripped in a post-Carboniferous plication and show Cordilleran strike; such exceptions do not invalidate the general rule. One is reminded of the prevailing E.—W. to N. 60° E. strikes in the Pre-Cambrian rocks of Lake Superior and eastward thereof, in the Canadian Shield. Is this agreement of structural trends in the two Pre-Cambrian areas fortuitous?

As already stated, the detailed structure of the Shuswap terrane offers a host of unsolved problems. In general,

the deformation of the bedded rocks seems to have consisted in warping and normal-faulting, especially the latter. The extremely abundant sills and other intrusive bodies have suffered nearly as much deformation as the invaded sediments.

The Western Geosynclinal Belt is structurally the most complex of the three principal provinces. All of its bedded formations, from the Carboniferous to the Cretaceous inclusive, are more or less intensely folded. The thick Carboniferous group has been specially affected by close-folding and mashing, with resulting turmoil in most of the Carboniferous areas.

Rocks of the Beltian to the Mississippian, inclusive, are only locally represented in this province, which except for limited areas was clearly a region of erosion during that long period. In our section the oldest known Paleozoic strata are Carboniferous (Pennsylvanian) in date. These lie unconformably upon the Shuswap terrane. A second unconformity is well exposed between the Pennsylvanian limestone and the Triassic near Kamloops. A third exists at the base of the Lower Cretaceous; a fourth at the base of the older Tertiary (Eocene?) geosynclinal deposits of the Strait of Georgia and Puget sound. An unconformity is registered at the base of the Oligocene in the Interior Plateaus and it probably corresponds to a deformation of post-Eocene date. A sixth unconformity is, of course, seen at the contact of the Pleistocene deposits with older formations.

NOTE ON THE IGNEOUS BODIES.

The sedimentary rocks of the Eastern Belt are, in our section, very seldom interrupted by igneous masses. The remarkable Ice River intrusion (see page 185) and the contemporaneous lavas in the Cougar formation (see page 136) are the only important eruptions observed in the railway zone between the Great Plains and the heart of the Selkirk range. On the other hand, the Western Belt shows not only a much larger number of unconformities, but also an incomparably greater amount of igneous activity.

Following the rule illustrated throughout the world, the downwarping of the western geosynclines has been

Looking north over the South Thompson river, from Campbell's ranch, 9 km. west of Ducks station. The creek bed in the middle of the view is located on the plane of unconformity between Pennsylvanian limestone (left, light-coloured outcrops) and Triassic conglomerate and basalt (right, dark-coloured outcrops).

accompanied by some contemporaneous volcanic action. Surface lavas of both central-eruption type and fissure-eruption type are found in the Pennsylvanian, Triassic, Eocene, and Oligocene downwarps of the Western Belt. In our section the volcanics of the Triassic and Tertiary are much thicker than the sediments of their respective dates. The Western Belt is, in fact, a volcanic province of the first order, whether considered as to volume of extravasated material, as to persistence of eruptivity in geological time, or as to area of country still covered by the lavas. The great cone of Mt. Baker, south of the railway at Mission Junction, represents Pleistocene-Recent vulcanism.

Batholithic intrusions are very rare in the Eastern Belt and are entirely absent in the railway section. They cut the Paleozoic strata of the Western Belt on a scale unmatched elsewhere in the world except, perhaps, in the Pre-Cambrian terrane of Eastern Canada, Fennoscandia, etc. The composite Coast Range batholith of British Columbia and Alaska is about 1200 miles (1930 km.) in length, with an average width of nearly 90 miles (144 km.). The railway section crosses it in the stretch between Lytton and Vancouver. It is composed of granodiorite and quartz diorite, with diorite, biotite granite, syenite, and allied types. There is clear evidence of successive intrusion but it is agreed that the general date of irruption for the greater part falls in the period from the latest Jurassic to the early Cretaceous. In our section the late Jurassic is the preferred date. Yet it is probable that this batholith, like those in Washington State and in the Kootenay district of British Columbia, received large increment or else batholithic replacement in post-Cretaceous time. In the railway section itself such Tertiary batholiths have not yet been proved and the earlier date is generally accepted for many smaller batholiths east of the Fraser river as well as for the Coast Range body. Some of the little sheared granitic masses cutting the western part of the Shuswap terrane are tentatively referred also to the late Jurassic.

These various bodies illustrate again and again the cross-cutting and apparently bottomless relations of true batholiths. The main contacts and the attitude of roof-pendants are eloquent in favour of the replacement theory of origin and strongly oppose the "laccolithic" theory. Evidence on this fundamental matter has been collected by: Clapp

in Vancouver Island; by Dawson, Bowen, Camsell, Le Roy, Bancroft and Daly in the Coast range; and by Daly in the Belt of Interior Plateaus. Their conclusions agree with many recent results of study in the Alaskan and United States portions of the Western Belt.

GENERAL HISTORY.

The earliest event demonstrated in the rocks of our section is the long-continued erosion of a silicious(granitic or gneissic) land surface older than the Shuswap series. No actual representation of this ancient mass has been discovered, but its existence is inferred from the abundant development of clastic, sandy and argillaceous beds of Shuswap age in south-central British Columbia. This deposition continued long, though it was often interrupted by the precipitation of limestone (e.g., Sicamous formation.) Clastic and chemical sediments together formed a geosynclinal mass several kilometres in thickness. Within it there is no sign of unconformity. Toward the close of this epoch of sedimentation and before any notable deformation of the geosyncline, basic lavas broke through the earth's crust and buried the older deposits very deeply (Adams Lake greenstone).

The lower members of the series were drastically affected by static metamorphism, whereby sediments and lavas became converted into true crystalline schists—metargillites, phyllites, and other mica schists, quartz-sericite schists, calc-schists, chloritic and uralitic schists. Excessive fissility essentially parallel to bedding-planes was thus imposed upon the Shuswap series. It was then invaded by granitic magma which sent off-shoots into the easily split schists, in the form of innumerable sills, laccoliths, and dykes, on a scale seldom matched. The plutonic invasion took place by successive stages, so that older intrusions are cut by younger. As so often the case, the youngest magmas were aplitic or pegmatitic in habit. This salic material forms countless small bodies in the Shuswap terrane. Practically all these intrusions, except the youngest aplites and pegmatites, were themselves subjected to static metamorphism, converting them into orthogneisses. The resulting schistosity, generally well developed, is sensibly parallel to the stratification planes of the adjacent sediments.

These intrusions must have been accompanied by some deformation of the Shuswap series. In any case, the plutonic invasion was followed by erosion which bit deeply into the new terrane—a process long continued, implying great uplift above baselevel. The uplift was, however, not accomplished as an incident of intense folding. The average dip of the Shuswap rocks is today low. It must have been lower in pre-Beltian time, for the planes of schistosity and sill-contacts of the Shuswap are nearly parallel to the basal beds of the Beltian system at Albert Canyon and have been upturned to angles of 45° to 55° since Beltian time. The pre-Beltian deformation may well have developed a broad geanticline accidented by slightly tilted fault-blocks. Their average strike possibly corresponded with the present dominant strike of the terrane, namely, about N. 70° E.

The first sediments formed by the erosion of the Shuswap terrane have nowhere been identified. A great mass of it had already been removed before the region about Albert Canyon was depressed below sea and was covered by the lowest exposed bed of the Beltian system. That bed was a little-washed arkose sand, in mineralogical composition differing but little from the shell of secular weathering on the Shuswap orthogneiss beneath. It is probable that this unconformity represents the preliminary erosion of the Shuswap bedded series at this locality.

With the geanticlinal uplift of the pre-Beltian terrane, the oldest known structure visibly paralleling the existing Cordilleran axis was developed. The zone roughly represented by the Western Geosynclinal Belt now became a land mass and the zone represented by a large part of the existing Eastern Belt become an elongated basin of deposition (largely, if not wholly, marine in our section). The floor of the basin slowly subsided and upon it the Rocky Mountain Geosynclinal was accumulated. More or less continuously, from the beginning of the Beltian to the close of the Mississippian, this prism increased in thickness; during the Middle Cambrian it was greatly widened by marine transgression far to the eastward, if not to the westward, of the initial shore-lines. Detailed study of the sediments shows that their clastic materials, even as far east as the Front range of the Rockies, were largely derived from the land on the west, though a small proportion

was washed into the geosyncline fron land masses located in the longitudes of Montana and Wyoming.

In Arizona, Colorado, and elsewhere in the United States, the early Cambrian was a time of erosion following local deformation in the Rocky Mountain Geosynclinal area; and in the late Middle Cambrian a re-submergence, contemporaneous with the marine transgression elsewhere, restored conditions of sedimentation in the zone. In British Columbia and Alberta, however, there appears to be perfect conformity throughout the Cambrian. Opinions differ as to the existence of an erosional break at the base of the Lower Cambrian in the Rockies. Walcott has announced the existence of an unconformity in the rocks of the Bow valley but later observations by Dı. Allan and by the present writer indicate that the break at this horizon must in any case be local and does not represent a long interval of time.

As yet it is impossible to locate the line of maximum thickness for the geosynclinal. In the railway section the Beltian and Loweı Cambrian strata grow thinner as they are followed eastward into the Rocky mountains, where the Middle and Upper Cambrian strata have their greatest known strength.

Next to the clastic material won from the adjacent lands, the most abundant constituent of the Rocky Mountain Geosynclinal is carbonate, chiefly limestone with some true dolomite. All of the pre-Ordovician carbonate-rock and most of the younger limestone and dolomite seems to be best explained as chemical precipitates. The total of the maximum thicknesses recorded for the carbonate rocks is more than 6,000 metres (20,000 feet).

Though contemporaneous vulcanism is recorded in this great prism at various horizons of the 49th Parallel section as well as elsewhere in the United States, it has added very little to the bulk of the geosynclinal at the Canadian Pacific section. So far as now known, the only occurrences of lava are those found in the Beltian Cougar formation.

In the Pennsylvanian (Carboniferous) period the geosyncline was enlarged both eastward and westward on a scale probably surpassing the marine transgression of the Middle Cambrain. Pennsylvanian sediments, chiefly limestone, were laid on the prism and in yet greater thickness limestones, shales, and more silicious beds were

now deposited in the Western Belt, which for the most part had so long remained above sea. The exact sources of supply for this fragmental detritus can not be fully determined. It is possible that islands of the Shuswap rocks still remained, and probable that parts of the Rocky Mountain Geosynclinal were upwarped, so as to suffer erosion during the Pennsylvanian. We know more definitely that some of the sedimentary matter in these rocks of the Western Belt was derived from the erosion of contemporaneous volcanoes. Great eruptions of basalt and basic andesite were widespread in the Western Belt during this period.

The Permian period has left no record of rock formation in the Western Belt but seems to be represented by continued deposition in the Eastern Belt (Upper Banff shale, 1,400 feet; 427 m. thick).

West of the Shuswap Lakes region the Pennsylvanian strata were at least locally subjected to moderate deformation, followed by erosion. These events anticipated the deposition of the Triassic shales and limestones, among which exceptionally heavy flows and pyroclastic masses of basalt were erupted. This vulcanism was widespread in the Western Belt, from Alaska to California. In British Columbia it took the form of heavy fissure eruptions with subordinate central eruptions. Few lava formations are as massive as the extensive and very thick basalts of the Nicola group. It is not certain that Jurassic sediments are represented anywhere in the railway section of the Western Belt. Hence the history of the Jurassic period is here obscure. From the analogy of other regions, particularly California, it is concluded that this part of the belt was strongly folded during the closing stage of the Jurassic.

In the Eastern Belt the Paleozoic era was closed by a broad upwarping, by which the sea was largely withdrawn from the Rocky Mountain geosyncline. It is probable that at least the western half of this belt in our section has been out of water ever since and that conditions of erosion there prevailed in the early Mesozoic. The upper Jurassic of the eastern foot-hills is conformable with the Cretaceous of the Great Plains and, like the latter, was probably in piedmont relation to the Cordillera Eastern Belt The late Jurassic orogeny, so powerful in the Western Belt, did not seriously deform the Paleozoic

strata of the Rocky mountains; upon those the Jurassic and Cretaceous lie with apparent conformity. In the general absence of Mesozoic sediments in the Middle ranges of British Columbia, it is a delicate, still unsolved problem as to how far the western part of the Eastern Belt was mountain-built during the Jurassic. Perhaps the information will be found along the new Grand Trunk Pacific Railway line.

The late Jurassic folding in the Western Belt was immediately followed by granitic intrusion on a grand scale, whereby the enormous Coast Range batholith was outlined, if not largely completed. Many smaller batholiths and stocks were simultaneously intruded into the older rocks of Vancouver island and of the broad tract between the Coast range and the Selkirks.

From that time to the present both Eastern and Western belts of the Cordillera have witnessed subaerial erosion. Near the line of the present Pacific shore and also in the eastern foot-hill zone of the Rockies, local geosynclinals of great depth were formed in the Cretaceous. Examples are: the Pasayten geosynclinal, stretching from west-central Washington to and beyond the Fraser valley at North Bend and Lytton; the Queen Charlotte geosynclinal, west of the Coast range; and the Crowsnest geosynclinal of the Eastern Rockies. Sediments of both Lower and Upper Cretaceous age occur in these local downwarps of Cordilleran trend.

With the completion of the thick Cretaceous prisms, the conditions were ripe for renewed mountain-building and the Laramide revolution deformed most of the Canadian Cordillera. As in the more limited Jurassic revolution, the major thrusts were directed from the Pacific side but they were now, for the first time since the pre-Beltian period, of pronounced effect at the extreme eastern limit of the Eastern Cordilleran Belt. All observers agree that the major deformation of the Rocky Mountain Front ranges took place at this time. Opinions differ as to the date of the great overthrust by which those ranges have advanced outwards, over the Great Plains. Willis has postulated a mid-Tertiary date for the Lewis thrust at the International Boundary, but the present writer is inclined to regard it and the similar thrust in Alberta as incidents of the Laramide revolution [**6**, p. 340; and **11**, Part I p. 94].

Thus, at the dawn of the Tertiary the Cordillera was developed with full vigour of mountainous relief. Its volume in British Columbia, measured above sea level, was then probably at its maximum. Its general history is henceforth one of erosion coupled with intermittent vulcanism of great intensity and with diastrophic movements which were of great importance but of an order less than the revolutionary. In the absence of a widespread sedimentary record in the mountain chain, it is difficult to state Tertiary events in an orderly, quantitative way. Long chapters in the Tertiary history can only be written in the future, after modern physiographic methods have been applied in the as yet unmapped portions of British Columbia.

In the Canadian Pacific section no marine sediments of Tertiary age have been definitely reported. The Eocene geosynclinal of Puget sound was doubtless continued into the region of the Strait of Georgia and lower Fraser valley; but this irregular prism represents an intermont basin, in which much of the deposition was subaerial or in fresh or brackish water. There resulted one of the thick stratified masses necessarily developed in Eocene basins from the wasting of the new, vigorous mountain chain. It is probable that the Belt of Interior Plateaus saw, in this period, a moderate amount of local volcanic action, paralleling the greater Eocene eruptions of Central Washington and of the Coast region. The eastern Cordilleran Belt carries no rocks of this period, which was apparently occupied throughout by erosive activity.

The Oligocene continued this erosion across the entire chain, but was marked in the Western Belt by long-continued emission of basalts, chiefly of the fissure-eruption type. This vulcanism involved much disturbance of drainage system. Local basins were formed and became filled with gravels, sands and muds, bearing fresh-water fossils (Tranquille group).

The Western Belt became affected by moderate orogenic movement, whereby the Oligocene lavas and sediments were locally upturned, sometimes to vertical position. This deformation is not yet accurately dated, but may prove to be of late Oligocene date. Though the local upturning was so pronounced, the Tertiary lavas of British Columbia were, in general, little disturbed from their original, flat attitudes, and it is reasonable to suppose that similarly

large surfaces underlain by non-volcanic rocks were not greatly deformed.

The Miocene was a time of general erosion across the entire Cordillera at our section.

The Cordilleran topography at the beginning of the Pliocene was evidently highly complex in origin and of

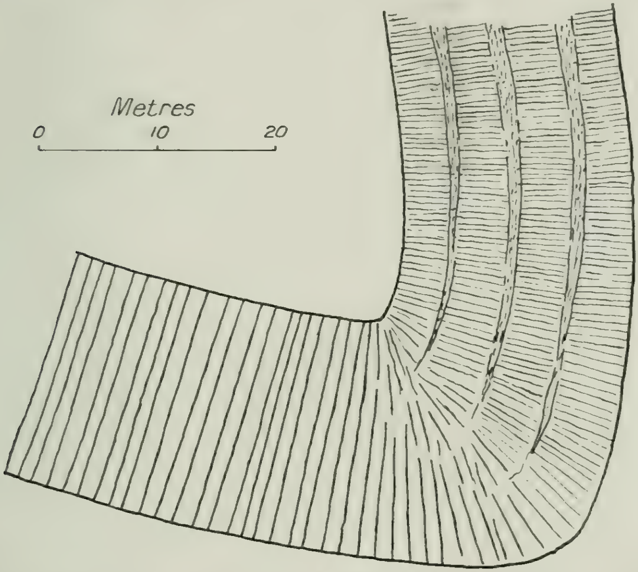


Diagram drawn to scale, showing development of columnar jointing in Tertiary basaltic flow near Ducks station. The gently dipping limb of the syncline is composed of regular columns of great size. The upturned limb is composed of four sets of regular but much smaller columns. The latter seem to have developed through orogenic stresses superposed on original cooling stresses.

great variation in age. Large areas had been undergoing erosion since the closing days of the Paleozoic; other areas, since the Triassic; others, since the late-Jurassic revolution; still others, since the Laramide revolution; while practically the whole Cordillera, except the part covered by Tertiary volcanics or local pockets of earlier Tertiary sediments, was being eroded during Eocene, Oligocene and Miocene times. We may well believe that, in places, the unceasing erosion of the whole (pre-Pliocene) Tertiary era, in spite of post-Oligocene deformation, had virtually produced local or widespread peneplains. Elsewhere moun-

tain torsos must have been the rule, except on the lava plains. In short, the early Pliocene Cordillera was a torso landscape, locally veneered with, and smoothed by, basaltic floods. It was this topographic composite, already close to sea level, which early Pliocene erosion somewhat further reduced toward a base level of fairly constant position.

Toward the close of the Pliocene all or nearly all of the Canadian Cordillera seems to have been elevated, to heights varying considerably, but reaching maxima of from 2,000 to 4,000 feet (610 to 1,220 m.). The streams so rejuvenated have had time to sink deep valleys in all three of the great Cordilleran Belts. This two-cycle topography is specially well illustrated in the Belt of Interior Plateaus, but it can be discerned in the Rocky Mountain trench, in the region around Revelstoke, and elsewhere along the railway section. The plateaus of the interior have been thus isolated from one another. In part, they represent dissected lava tables; in part, dissected local peneplains of pre-Miocene date; in part, dissected mountain torsos, reduced during the early Tertiary and the Mesozoic. There is no evidence that a *general* peneplain was developed over this part of the Cordillera at any time; nor is it proved that the upland facets of the Interior Plateaus were due to general peneplanation of that broad belt in late Miocene and early Pliocene time. A superficial study of the Interior Plateaus might lead to that conclusion; in reality, the upland relief has been conditioned by several pre-Miocene erosion cycles.

The Pleistocene glaciers gradually overwhelmed a mature to sub-mature topography. Their work represents a chapter of Cordilleran history already sketched; some of its details will be noted in annotations on the route to be followed by the excursionists. The recent changes in the late Glacial landscape are relatively slight and for the most part are too obvious to need formal statement in this place.

SPECIALLY NOTEWORTHY FEATURES.

In the midst of a multitude of problems and ascertained facts, certain aspects of the Cordilleran geology are worthy of special attention. Some of these are here listed for the convenience of the excursionists.

1. The great development of Cambrian sediments; their extraordinary richness in fossiliferous horizons and in new species and genera; the perfection with which some of this fauna has been preserved.

2. The unusually complete exposures and vast thickness of the Beltian system of rocks conformably underlying the Lower Cambrian.

3. Illustration of geosynclinal prisms of various ages.

4. The large area of pre-Beltian ("Archean") formations, including sediments, volcanics and orthogneisses.

5. Specially clear illustration of the efficiency of static metamorphism (Shuswap terrane and Beltian system).

6. The wide extent and great thickness of basic volcanics referred to the Triassic and to the mid-Tertiary.

7. The section through the Coast Range batholith, probably the most widely exposed intrusive mass of post-"Archean" date.

8. The evidences of a chemical origin for limestones and dolomites thousands of metres in thickness.

9. The opportunity of passing through the Rocky Mountain Geosynclinal into the terrane which furnished most of its clastic materials.

10. A view of the important unconformity at the base of the Rocky Mountain Geosynclinal.

11. The sections through the Rocky Mountain and Purcell trenches, two of the more remarkable depressions in the North American Cordillera.

12. The nature of the railway section as favourable to the discovery of field facts showing the relative shallowness of the earth-shell involved in orogenic folding.

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Indexes to North American Geology; Bulletins No. 127, 188, 189, 301, 372, 409, and 444 of the United States Geological Survey.

In these most of the important publications will be found under the names— G. M. Dawson, McConnell, McEvoy, Camsell, Walcott, Allan, and Dowling.

Especially to Dawson, the master in reconnaissance, geology owes the broad outlines already fixed for the Canadian Cordillera. A useful summary of its geology with leading references, is Dawson's 'Geological Record of the Rocky Mountain Region in Canada,' published in the Bulletin of the Geological Society of America, Vol. 12, 1901, pp. 57–92. His report on the Area of the Kamloops Map-sheet (427 pages) in Volume 7 of the Annual Reports of the Geological Survey of Canada is the most detailed work yet published on any large part of the railway section. In Volume 53 of the Smithsonian Miscellaneous Collections (1908), will be found C. D. Walcott's principal writings on the Cambrian and pre-Cambrian geology of the Rocky mountains in Canada.

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ROCKY MOUNTAINS (Bankhead to Golden).

BY

JOHN A. ALLAN.

STRATIGRAPHY.

COLUMNAR SECTION.

In the section across the Rocky mountains, between the Cascade trough near Banff to Golden and the Columbia valley, all the geological systems from the Pre-Cambrian to the Cretaceous inclusive, except the Triassic, are represented.

As shown in the tabulated section given below, the stratified rocks aggregate more than 52,628 feet (16,040 m.) in thickness. The thin-bedded strata, mostly shales, make up 23,730 feet (7,235 m.); the limestones, 20,528 feet (6,255 m.); the quartzites and sandstones, 8,370 feet (2,550 m.).

The relation between the Silurian and the Devonian systems is not shown in this area, because the Cambrian, Ordovician and Silurian formations are exposed mainly on the western slope of the Rocky mountains, while the remaining systems are exposed wholly on the eastern side of the Continental watershed.

Table of Formations.

System.	Formation.	Approx. Thickness. Feet.	Approx. Thickness. Metres.	Lithology.
Recent and Pleistocene.	Fluviatile			Gravel, sand.
	Lacustrine			Gravel, sand, clay, silt and conglomerate.
	Glacial			Till.
	Erosion surface.			
Post-Cretaceous?	Igneous rock			Nephelite syenite, ijolite, urtite, jacupirangite, etc., with dykes.
Cretaceous	Upper Ribboned sandstone	550+	168+	Thin-bedded sandstone and shale with hard bands of sandstone.
	Kootenay Coal measures	2,800+	853+	Sandstone and shale with coal seams.
	Lower Ribboned sandstone	1,000+	305+	Thin-bedded brown sandstone and shale.
Jurassic	Fernie shale	1,500+	457+	Dark brown to black arenaceous shale; weathers into lens-like fragments.

Permian	Upper Banff shale	1,400+	427+	Dark brown arenaceous shale; weathering reddish and yellowish.
Mississippian	Rocky Mountain quartzite	800	244+	White to gray quartzite and arenaceous siliceous limestone.
	Upper Banff limestone	2,300+	701+	Thick-bedded dark gray limestones with numerous thin cherty layers underlain by thin-bedded limestone and shale; weathering gray.
Pennsylvanian	Lower Banff shale	1,200	366+	Black to dark gray shale, argillaceous and calcareous; weathering light brown.
	Lower Banff limestone	1,500+	457+	Thick-bedded gray limestones with numerous dolomitic segregations.
Devonian	Intermediate limestone	1,800+	548+	Thin-bedded limestones, with alternating more massive layers of gray dolomitic and siliceous limestone.
	Sawback limestone (age ?)	3,700+	1,127+	Thin-bedded limestone interbedded with less resistant layers and brownish and yellowish shale.
Contact relations not known.				
Silurian	Halysites beds	1,850+	563+	Dolomites and quartzites weathering light gray to white, with shale interbedded.

TABLE OF FORMATIONS—*Concluded.*

System.	Formation.	Approx. Thickness.		Lithology.
		Feet.	Metres.	
Ordovician	Graptolite shales	1,700+	518+	Black and brown fissile shales.
	Goodsir shale	6,040+	1,842+	Cherts, cherty and dolomitic limestones, siliceous and calcareous slates and shales.
Upper Cambrian	Ottertail limestone	1,725+	526+	Massive blue limestones with cherty and shaly bands.
	Chancellor	4,500+	1,372+	Thinly laminated gray argillaceous and calcareous meta-argillites and shales; weathering reddish, yellowish and fawn; underlain by highly sheared gray shales, slates, argillites and phyllites in Ottertail valley.
	Sherbrooke	1,375	419	Thin-bedded oolitic, arenaceous or dolomitic limestones.
	Paget	360+	110+	Massive bluish gray limestones, with oolitic bands of dolomitic limestone.
	Bosworth	1,855+	565+	Massive gray arenaceous and dolomitic limestone; weathering yellowish buff; interbedded with greenish siliceous shale; weathering, red, yellow and purple.

Middle Cambrian	Eldon	2,728	831	Massive-bedded arenaceous limestones forming cliffs and castellated crags.
	Stephen	640	196	Thin-bedded limestone, and shale; includes "Ogygopsis shale" in Mt. Stephen and "Burgess shale" in Mt. Field.
	Cathedral	1,595	486	Thin-bedded arenaceous and dolomitic limestones.
Lower Cambrian	Mt. Whyte	390	119	Siliceous shale, sandstone and thin-bedded limestone.
	St. Piran	2,705	824+	Ferruginous quartzitic sandstone.
	Lake Louise	105	32	Compact grayish siliceous shale.
	Fairview	600+	183	Ferruginous quartzitic sandstone. Local basal conglomerate and coarse-grained sandstone.
	Conformable in some places			
Pre-Cambrian	Hector	4,590+	1,399+	Gray, green and purple siliceous shale with conglomerate interbedded.
	Corral Creek	1,320	403	Quartzitic and coarse-grained sandstone with shale interbedded.
Base not exposed. Total thickness		52,628+	16,041+	

RESUME OF SECTION.

	Feet.	Metres.
Cretaceous	4,350+	1,326
Jurassic	1,500+	457
Permian	1,400+	427
Carboniferous	5,800+	1,768
Devonian	1,800+	548
Devonian (?)	3,700+	1,127
Silurian	1,850+	563
Ordovician	7,740+	2,360
Upper Cambrian	9,815+	2,992
Middle Cambrian	4,963	1,513
Lower Cambrian	3,800+	1,158
Pre-Cambrian	5,910+	1,802
Total	52,628+	16,041+

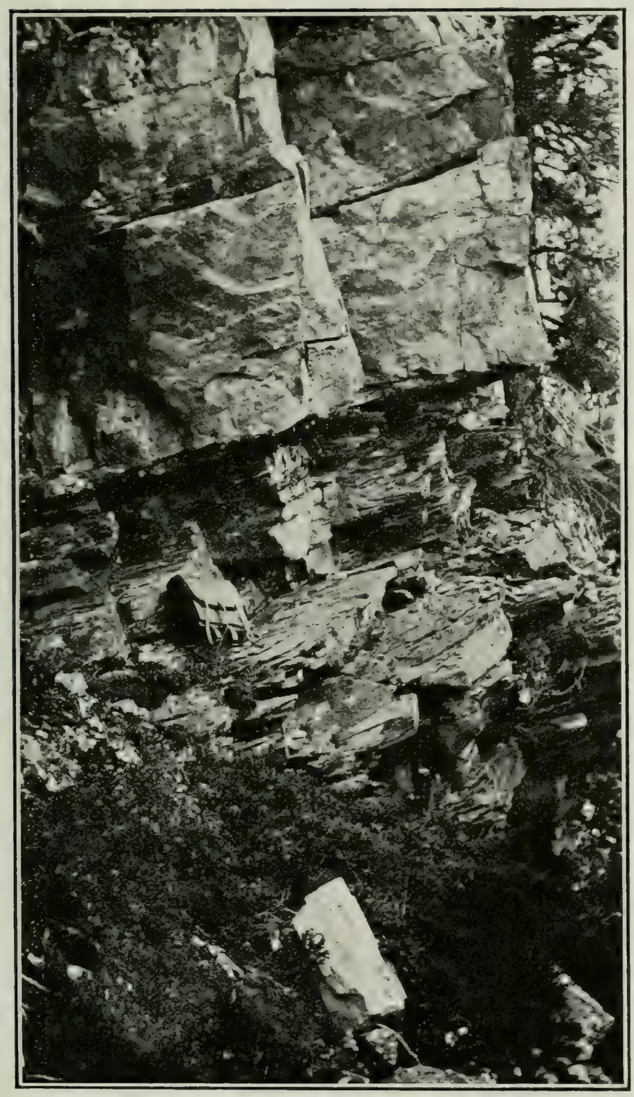
PRE-CAMBRIAN.

The Pre-Cambrian series is distributed along the floor and sides of Bow river valley from the base of Castle mountain, where it becomes faulted off against the younger Paleozoic rocks, to the head waters of the Bow river.

The contact between the Pre-Cambrian and the Cambrian is seldom exposed. It was examined at three localities. At one exposure in Bath Creek valley, near the summit of the Rocky mountains, the contact is a conformable one, while in two other localities in which the contact was exposed, there is a noticeable unconformity between the beds of the two systems. In one case the Pre-Cambrian shales were dipping 31 degrees S. 55° W., and the Lower Cambrian quartzites had a dip of 35 degrees S. 5° W.

The rocks in the Pre-Cambrian series, with the three lowest formations of the lower Cambrian, were formerly called the 'Bow River Group' by McConnell [**2,** p. 29].

Corral Creek Formation.—This formation includes the lowest beds exposed in the Rocky mountains, along this section. This series consists of gray sandstone underlain by a coarser quartzitic sandstone, with an arkose-like conglomerate at the base. The lowest beds are exposed in a railway cut two miles (3,249·2 m.) east of Laggan station. This rock is made up of small pebbles and grains of quartz, and angular crystals of white and pink feldspar. The cement is made up of finer material of



Contact of the Pre-Cambrian shales (Hector) and the Lower Cambrian quartzites. Exposed in Bath creek west of Laggan.

the same composition. The nature of this rock suggests shallow-water or near-shore conditions of origin.

Hector Formation. The beds in this formation consist of gray, purplish, and greenish shale interbedded with bands of conglomerate 15 m. to 75 m. thick. The best exposure is in the Bow range east of Storm mountain, where the formation has a minimum thickness of 4,590 feet (1,399 m.). It thins out towards the northwest; in Mt. Temple, Walcott measured over 2,150 feet (655 m.), and at Fort mountain towards the head of Corral creek he obtained a section 1,302 feet (397 m.) thick.

From one layer of shale (50 cm. thick), outcropping on the eastern base of Storm mountain and about 16 metres from the top of the series the writer collected fossil remains of a brachiopod-like shell about one-eighth of an inch in diameter. This is the only locality in which fossil remains have yet been found.

CAMBRIAN.

The Cambrian series is complete in this section with both lower and upper contacts exposed. There is a total thickness of over 18,578 feet (5,663 m.). This represents one of the thickest Cambrian sections yet measured in the world. It essentially consists of 3,800 feet (1,159 m.) of siliceous beds, principally quartzitic sandstone; 10,275 feet (3,132 m.) of calcareous and dolomitic limestone, and 4,500 feet (1,371 m.) of shale, much of which is calcareous. The various divisions of the Cambrian series have been made on paleontological and lithological evidence. The formations in the Lower and Middle Cambrian and the first three in the Upper Cambrian were named and measured by Walcott, [**7,** p. 204]; the remaining two formations were named and measured by the writer.

LOWER CAMBRIAN.

Fairview Formation.—The Fairview formation consists of brown and white quartzitic sandstone. Locally there is a basal conglomerate on the Pre-Cambrian shales; it consists of rounded pebbles of white quartz, up to 7 cm. in diameter, in a cement of quartz, feldspar and mica. The basal rock is more frequently a coarse sandstone with rounded and angular grains of quartz and feldspar,

5 to 15 mm. in diameter. Some of the quartz grains have a glassy, almost opalescent colour.

Lake Louise Formation.—As the name indicates, these beds are best exposed at Lake Louise. The formation has a total thickness of 105 feet (32 m.) and consists of a ferruginous siliceous shale. It weathers more readily than the beds below or above, so that the slopes are more gradual.

Mt. Temple, showing a complete Lower and Middle Cambrian section capped by Upper Cambrian, and underlain by Pre-Cambrian shales (covered by talus).

St. Piran Formation.—This formation consists of massive-bedded, ferruginous, quartzitic sandstone, with a total measured thickness of 2,705 feet (824 m.). These beds form steep escarpments wherever they are exposed. On the west side of Mt. Victoria the cliffs composed of these beds are over 2,500 feet high. The brown color of the rock is due to smoky quartz and small particles of mica in the cement.

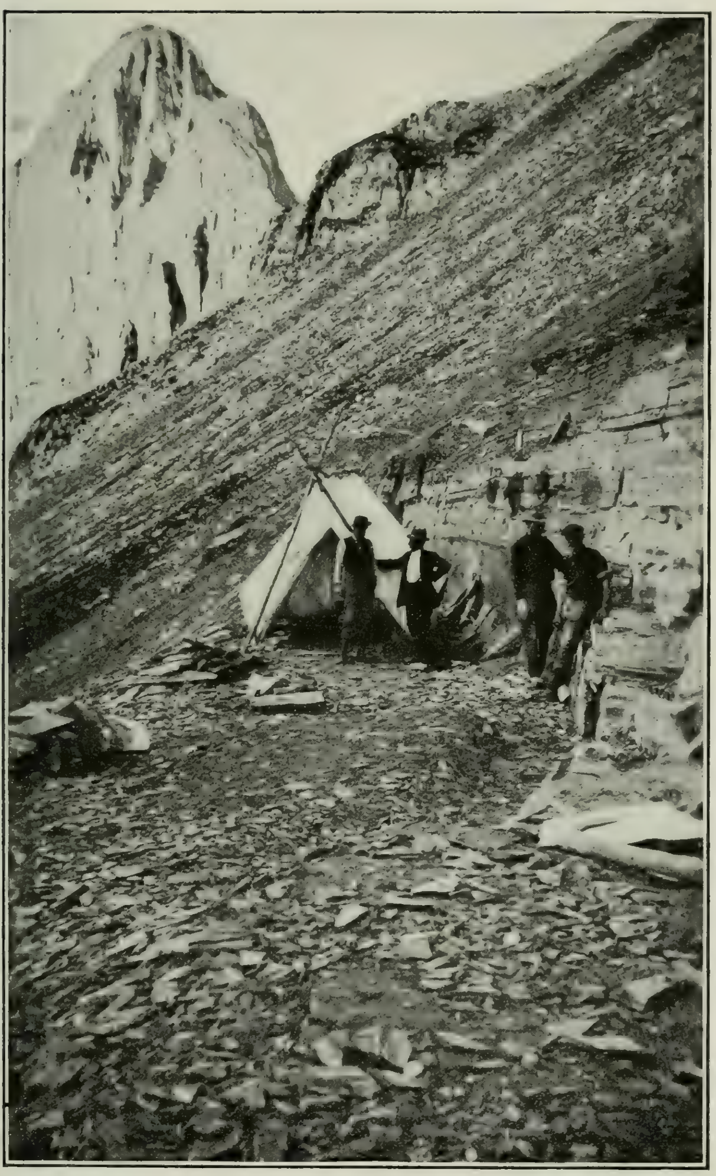
Mt. Whyte Formation.—In sharp contrast with the underlying massive quartzites, there is a thin series of siliceous and calcareous shales grouped as the Mt. Whyte formation. These shales are less resistant than the quartzite and form gradual slopes. Some of the layers contain numerous annelid borings and trails.

Cathedral Formation.—This formation consists of massive and thin bedded dolomitic limestone, which on the weathered surface becomes buff and gray. The more massive beds are arenaceous in their composition. It is on this formation that the Monarch mine in Mt. Stephen is situated, and other small mineral prospects in the Kicking Horse valley.

Castle Mountain, showing Cathedral limestone in the lower cliffs; Stephen formation in the talus covered slope; and the Eldon formation in the upper cliffs. (All Middle Cambrian).

Some of the limestone has become metamorphosed into marble. One of the best exposures of this rock is in Cathedral mountain, four miles (6·4 km.) east of Field.

Stephen Formation.—Although this formation is only 640 feet (196 m.) thick, yet it is quite important for the number and variety of fossils which it contains. It consists of shaly limestone and calcareous shale. These beds include the 'Ogygopsis shale' in Mt. Stephen, and the 'Burgess shale' in Mt. Field, on the opposite side of the valley. The former includes the widely known trilobite-bearing 'fossil bed,' while the latter includes the new 'fossil bed,' discovered by Walcott in 1910. From this bed he has obtained an extensive variety of Middle Cambrian organisms. Coelenterata, Annulata, Echinoder-



Fossil bed in "Burgess shale" on Mt. Field, showing character of the shale, method of quarrying for fossils, and temporary camp of C. D. Walcott.

mata and certain Arthropoda are abundantly represented [**10**].

Eldon Formation.—This formation has a thickness of 2,728 feet (831 m.) where it was measured in Castle mountain. It consists essentially of massive-bedded, arenaceous limestones, which form steep castellated crags on the erosion surface, thus making the formation readily recognizable wherever exposed. It is this formation which forms the steep escarpment about the upper part of Castle mountain.

The Mitre and Death Trap (pass) to the right. The cliffs on the right are of Middle Cambrian limestone in Mt. Lefroy. A typical bergschrund is shown around this portion of the Lefroy glacier.

UPPER CAMBRIAN.

Bosworth Formation.—This formation is exposed in the mountain of the same name on the Continental Divide. It consists largely of thin-bedded limestone with a few more thick-bedded layers, interbedded with siliceous and arenaceous shale. One band of shale makes a good horizon-marker because it weathers greenish, yellowish, deep red, and purplish.

Paget Formation.—A band of grayish oölitic limestone, typically exposed in Paget peak, on the west slope of Mt. Bosworth, has been placed in this formation. These beds can not be readily distinguished from the underlying limestone.

Sherbrooke Formation.—Arenaceous limestone at the base of this formation is overlain by thin-bedded limestone, including some oölitic and shaly layers. This formation includes the highest beds exposed in the Bow Range in the vicinity of Hector Pass.

The remaining Cambrian formations, the Ordovician, and the Silurian are all exposed in the western portion of the section between the Bow range and Columbia valley.

Chancellor Formation.—This formation consists essentially of shales which weather reddish, yellowish, fawn or gray. The uppermost 2,500 feet (762 m.) are gray met-argillites, well cleaved along the bedding planes, and weathering reddish and yellowish. These shales become much more highly cleaved towards the base of the formation, so that the lowermost, 2,000 feet (610 m.) thick, consist chiefly of phyllites and slates, with argillites and a few interbedded layers of shaly limestone. The ferruginous content in all the beds is high, so that the weathered surface is usually reddish or yellowish. This series floors Ottertail valley, underlies the Ottertail range, and makes up a large part of the Van Horne range.

Ottertail Limestone.—This formation consists almost entirely of blue limestone, massive towards the top and rather thin-bedded towards the base. It has a thickness of over 1,725 feet (526 m.) in the Ottertail range, where it is well exposed in an almost perpendicular escarpment along the east side of the range. The cliff-forming character of this formation marks it off very sharply from the shale formations below and above.

This limestone represents the highest series in the Cambrian in this portion of the Rocky mountians.

ORDOVICIAN.

Goodsir Shales.—This formation is best exposed in Mt. Goodsir, where it has a measured and estimated thickness of over 6,040 feet (1,841 m.). It lies conformably on the Ottertail limestone and consists at the base of almost 3,000 feet (914 m.) of alternating hard and soft bands of argillaceous, calcareous, and siliceous shale, which weather light yellowish, gray and buff.

The upper part of the formation consists of banded cherts, cherty limestones and dolomites, thin-bedded and

very dense, so that they weather into compact angular fragments. The beds in this series become very highly sheared in the Beaverfoot valley and the range to the west.

On both paleontologic and lithologic evidence the boundary between the Cambrian and the Ordovician in this district is placed at the top of the Ottertail limestone and at the base of the Goodsir shale.

Cambrian–Ordovician contact in Mt. Goodsir. The gray rock is the Ottertail lime-limestone, overlain by the dark-colored Goodsir shales.

Fossils were found near the base of the Goodsir formation at several localities, and have been determined by Walcott. The following new species have been identified from this series.:—

Obolus mollisonensis.
Lingulella? allani.
Lingulella moosensis.
Ceratopyge canadensis.

The presence of the Ceratopyge fauna places this formation at the base of the Ordovician, corresponding to the horizon of the Ceratopyge shale in Sweden.

The sedimentary series from Mt. Whyte to Goodsir, inclusive, were included by McConnell in his Castle Mountain group.

Graptolite Shales.—These beds have been so named by McConnell on account of the richness of certain layers in graptolites. The presence of this fauna determines the age of the formation as Ordovician.

The Graptolite shales consist of black, carbonaceous, and brown, fissile shale at the top, underlain by gray shales which grade into the underlying Goodsir formation.

The thickness of the formation varies and the lower contact is ill-defined, but a thickness of at least 1,700 feet (518 m.) is represented. These shales occur as two infolded bands in the Beaverfoot range.

SILURIAN.

Halysites Beds.—The Halysites beds consist chiefly of dolomitic limestone and white quartzite. This formation lies conformably upon the Graptolite beds. The character of the rock sharply distinguishes it from the older strata. The formation is terminated above by a fault contact or by an erosion surface. A measured section gave 1,850 feet (563 m.). The white quartzite is over 900 feet thick (274 m.). It is infolded with the graptolite beds in the Beaverfoot range. Some of the beds of dolomitic limestone are highly fossiliferous; corals are most abundant, but crinoids, brachiopods, and gastropods are also present.

This is the youngest formation exposed to the west of the Continental Divide, along this section of the Rocky mountains.

DEVONIAN.

Intermediate Limestone.—This formation consists of thin-bedded limestones, alternating with harder layers of gray dolomitic and siliceous limestone, which on the weathered surface becomes banded. In the Sawback, Vermilion Lake and Cascade ranges it is exposed, being repeated by reversed faulting.

The thermal sulphur springs at Banff occur in the Intermediate limestone. The rock is high in sulphur, derived by the decomposition of pyrite which the limestone contains; a strong odor of sulphide of hydrogen is given off when the rock is struck with a hammer.

Some of the beds are highly fossiliferous. Zaphrentis and brachiopods are the most abundant forms present.

The upper limit of this formation is not clearly defined as it is transitional into the Lower Banff shale.

Sawback Formation.—Underlying and conformable with the Intermediate limestone is a series of massive and thin-bedded, dolomitic limestone and shale, which McConnell has placed in the Cambrian. These form a wedge-shaped band in the Sawback range and lie between Mt. Hole-in-the-wall and Mt. Edith, with a broader exposure along the north side of the Bow valley. It has been possible to measure and estimate a thickness of about 3,700 feet (1,128 m.) but the actual thickness is believed to be much greater. Fossils have not yet been found in this series. Since they differ lithologically from the Cambrian beds in Castle mountain, which are largely Middle Cambrian, and from the Cambrian in the Bow range and to the west of this range, it is proposed to call this series Sawback limestone. The age of the formation is still in doubt but it is older than the Intermediate limestone, which is definitely known to be Devonian in age. These beds are lithologically closely related to some of the Silurian beds in the Beaverfoot range to the west.

MISSISSIPPIAN.

Lower Banff Limestone.*—This formation grades into the Devonian limestone below, so that it is not possible always to draw a sharp dividing line between these two formations. It is quite clearly defined on its upper contact, as the overlying formation is a shale. The beds consist of massive-bedded, gray limestone which forms steep escarpments wherever exposed on the slopes of a mountain.

This limestone forms the eastern cliffs of Cascade mountain, and Mt. Rundle; and the steeper eastern slopes of Sulphur mountain. Some beds are fossiliferous, and the formation is characterized by numerous fossil-like dolomitic segregations. Many of these resemble certain types of bryozoan remains.

Lower Banff Shale.—There are about 1,200 feet (366 m.) of shale included in this formation. These shales are black to dark gray in colour and weather brown.

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*Since Dr. Allan sent his MS. to press, Dr. H. W. Shimer has found that the fossils recently collected in this limestone show it to be largely if not wholly of Devonian age.

They are usually calcareous in composition, but certain layers are argillaceous and arenaceous. The lower contact of this series is sharply defined but at the top of the series the beds change to a shaly limestone difficult to distinguish from the overlying limestone. The shales weather out more easily than the limestone, so that a depression is always formed where these shales cut across a ridge. A leading fossil is *Spirifer centronatus*.

Pennsylvanian.

Upper Banff Limestone.—There are over 2,300 feet (701 m.) of beds included in this formation, which is well exposed in Sawback and Cascade ranges. The series is shaly at the bottom, but more massive towards the top. Cherty lenses and cherty shale interbedded with the lower shaly limestone help to distinguish this formation from the shales below. Fossils e.g., *Spirifer rockymontanus*, are quite abundant throughout the lower beds in this series.

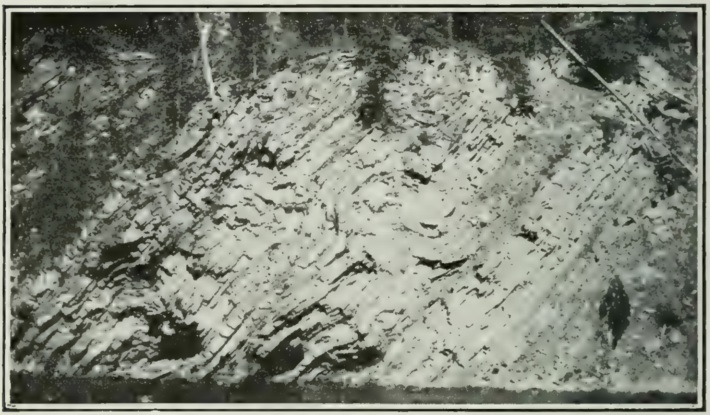
Rocky Mountain Quartzite.—This quartzite lies directly on the Upper Banff limestone. It represents a very sudden shallowing of the water, which, however, was not rendered muddy. The section in the Sawback range gave 800 feet (244 m.) as a maximum thickness. There is a rapid thickening of this formation to the east so that at Lake Minnewanka, 12 miles (19 km.) to the east, there are 1,600 feet of quartzite exposed. Certain portions of the formation are quite fossiliferous. These fossils e.g., *Euphemus carbonarius*, can most readily be found on the weathered surface.

This is the uppermost formation in the Carboniferous. The lower two formations have been grouped as Mississippian in age, while the upper two correspond to the Pennsylvanian. [**9**, p. 147].

Permian.

Upper Banff Shale.—This formation lies conformably upon the quartzite and consists of a series of brown, calcareous and arenaceous, often sun-cracked shales interbedded with thin layers of sandstone. The shales weather out more easily than the underlying formations, forming valleys such as those between the Cascade, Vermilion Lake, and Sawback ranges. More than 1,400 feet

(427 m.) of strata are represented in this section, but it is difficult to get an accurate measurement on account of the foldings and contortions within the beds. A leading fossil is *Schizodus*.



A typical view of the Upper Banff shale, exposed in Spray valley at Banff.

JURASSIC.

Fernie Shale.—No sharp line can be drawn between the Upper Banff and Fernie shales, except where fossils are found. The Fernie formation consists of black and dark brown, siliceous, very thinly laminated shales which break up into small fragments on the weathered surface. West of Banff it has a limited distribution, lying on the Upper Banff shale. East of Banff and on the north side of the Cascade trough, it forms a band about 1,500 feet (457 m.) thick. The Fernie shale was examined near Exshaw 6 miles (9·6 km.) east of the Gap. A certain layer was found to contain clay concretions of which the largest was 35 cm. in diameter. Another layer, 15 cm. thick, contained numerous bone fragments. One large reptile-like jaw-bone is 22 cm. long. There are many smaller fragments of bone and teeth. Ammonites are very common in the Fernie shale.

CRETACEOUS.

Lower Ribboned Sandstone.—The Cretaceous beds are exposed along the eastern base of Cascade mountain. The Lower Ribboned sandstone consists of alternating bands of brown-weathering sandstone and shale. This formation follows the bottom of the Cascade trough and is exposed on the road between Bankhead and the west end of Lake Minnewanka. The beds are here about 1,000 feet (305 m.) thick.

Kootenay Coal Measures.—This formation consists of 2,800+feet (853+m.) of sandstone and shale enclosing several workable seams of coal. There are fourteen seams exposed at Bankhead, where the coal is being mined, and nearly twice as many have been found at Canmore down the Cascade trough. The coal is bituminous and anthracitic. Several of these seams are being mined at Canmore. The coal measures are well defined between two massive sandstone bands which form roof and floor.

Upper Ribboned Sandstone.—This formation consists of thin-bedded sandstones and shales. It is exposed at the eastern base of Cascade mountain. The beds are wedged between the coal measures below, and a thrust plane above. Some of the uppermost Cretaceous beds were planed away when the older beds were thrust over them. There are about 550 feet (168 m.) of beds exposed in Cascade mountain, but this formation becomes thicker where it is exposed to the northwest and southeast of this section.

POST-CRETACEOUS.

Igneous Complex.—The only igneous rock in the Rocky Mountain section is represented by the Ice River intrusive complex, which has the form of an asymmetrical laccolith with a stock-like conduit. It has an area of about 12 square miles (31 sq. km.).

The rocks of the complex are all alkaline in composition, ranging from nephelite syenite and sodalite syenite through urtites and ijolites, to a jacupirangite or alkaline pyroxenite. These diverse types represent a complete petrographic series with intermediate facies.

The age of the intrusion is believed to be post-Cretaceous as determined by structural and correlation evidence.

PLEISTOCENE AND RECENT.

The unconsolidated material is represented by three types of deposits as shown in the section. The fluviatile and lacustrine deposits appear in terraces about the sides of the larger valleys, while the former also floors the broad flood plains of the main streams, such as the Bow, the Kicking Horse, the Beaverfoot and the Yoho.

Glacial till veneers the more gradual slopes of the various ranges, to an elevation at least 9,000 feet (2,743 m.) above sea-level.

ANNOTATED GUIDE.

(Bankhead to Golden).

BY

John A. Allan.

Miles and Kilometres.

79·5 m. 127·2 km. from Calgary.

Bankhead—Alt. 4,510 ft. (1,375 m.). This station lies to the western edge of the Cascade coal basin described by Dowling [**1**].

About one mile east of this siding the railway leaves the bottom of Cascade valley and, turning at 90 degrees to the southwest, passes between Cascade mountain on the north, and Tunnel mountain on the south. This was at one time the course of Bow river, but the channel was obstructed by the gravels brought down by Forty Mile creek, as well as by the moraine left by the continental ice sheet, so that now the Bow passes through this range between Tunnel mountain and Mt. Rundle.

The structure of the beds in Cascade mountain is well shown in the cliff to the right of the railway. The beds are steeply dipping to the west and terminate in a precipitous cliff on the east. The cliffs at the base are Intermediate limestone (Devonian), overlain by Lower Banff limestone (Lower Carboniferous). The Lower Banff shale above (also Lower Carboniferous) weathers into talus-covered slopes. The mountain is capped by Upper Banff limestone and

Miles and Kilometres.

Rocky Mountain quartzite (Upper Carboniferous). An overthrust fault-line scarp defines the steep eastern face of this mountain; the Devonian limestones are thrust over the Cretaceous coal measures. This fault-line defines the southwest side of Cascade valley. It is exposed in the base of the Three Sisters, and extends to the southeast along the eastern face of the Livingstone range at the Crowsnest Pass, and into Montana, where it is known as the "Lewis thrust." It has not been possible to measure the actual amount of displacement, but there is a vertical throw of about three miles (4·8 km.) in Cascade mountain. McConnell [**2**] has estimated that the front ranges of the Rocky mountains have been thrust about seven miles (11·2 km.) over the plains to the east, but it it not possible to measure the horizontal displacement in the Cascade Mountain thrust fault.

A spur runs from Bankhead station to the Bankhead coal mines, about two miles (3·2 km.) to the northeast. These mines are owned and operated by the Canadian Pacific Railway Company. They are situated in the Kootenay coal measures which are Lower Cretaceous in age. The coal is bituminous and semi-anthracite. The plant is well equipped with a large breaker and a briquetting mill.

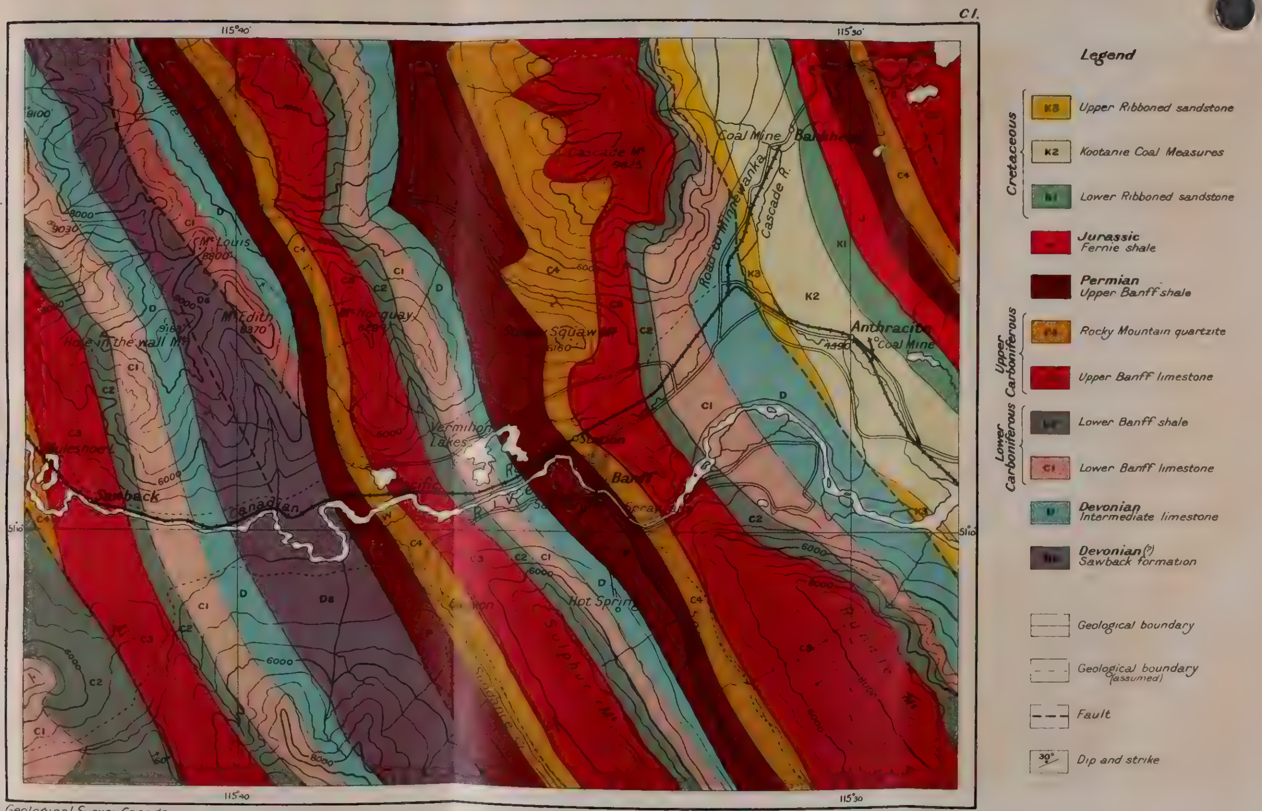
Between the coal mines and Lake Minnewanka a section along Cascade river exposes Cretaceous, Jurassic, Permian and Upper Carboniferous beds. This section has been studied in detail by H. W. Shimer [**3**]. Fossils are abundant, expecially in the Rocky Mountain quartzite. For a portion of this distance the driveway follows along the top of a morainal ridge. In Pre-Pleistocene time Cascade river drained out by Lake Minnewanka and Devil's Gap to the plains, but in recent time it has cut through the thick morainal detritus and has joined Bow river four miles (6·4 km.) east of Bankhead station.

Miles and Kilometres.

82 m. **Banff**—Alt. 4,521 ft. (1379 m). This is the
131·2 km. gateway to the Rocky Mountain National Park. This reservation covers 5,732 square miles (14,330 sq. km.), and contains many features of interest. Some of those to be visited are the hot sulphur springs, sulphur caves, Sulphur Mountain observation station, and the buffalo paddock. Looking west from the station are seen the snow-capped peaks of the Bourgeau range, ten miles (16·1 km). distant. The town lies west of Tunnel mountain. On the north side of the valley are Cascade mountain and a subsidiary ridge, Stoney Squaw mountain, in which is shown the eroded end of an asymmetrical anticlinal fold.

A few yards to the west of the station Bow river turns sharply to the southeast, and after passing the town and cascading over a very picturesque fall, it is joined by the Spray. At this point, close to the Banff Springs hotel, the river is diverted at right angles to the east and passes between Tunnel and Rundle mountains. The valley of the Spray river is floored with soft Permian and Jurassic shales. The accompanying figure shows a typical view of the Upper Banff shale (Permian), exposed in Spray valley. This valley is defined by a fault so that the beds in Sulphur mountain repeat those exposed in Cascade and Rundle mountains. The Fernie shales (Jurassic) are characterized in certain layers by the abundance of ammonites.

On the east slope of Sulphur mountain are situated the hot sulphur springs. The upper one is 500 feet (152·5 m.) above the town. The water comes from the orifice at a temperature of 114·2 degrees Fahr. (45·6° C). This sulphuretted water has a marked medicinal effect, and many people visit Banff on this account. A second or middle hot spring is 200 feet (60 m.) lower down the slope, and a mile and a half (2·4 km.) farther to the



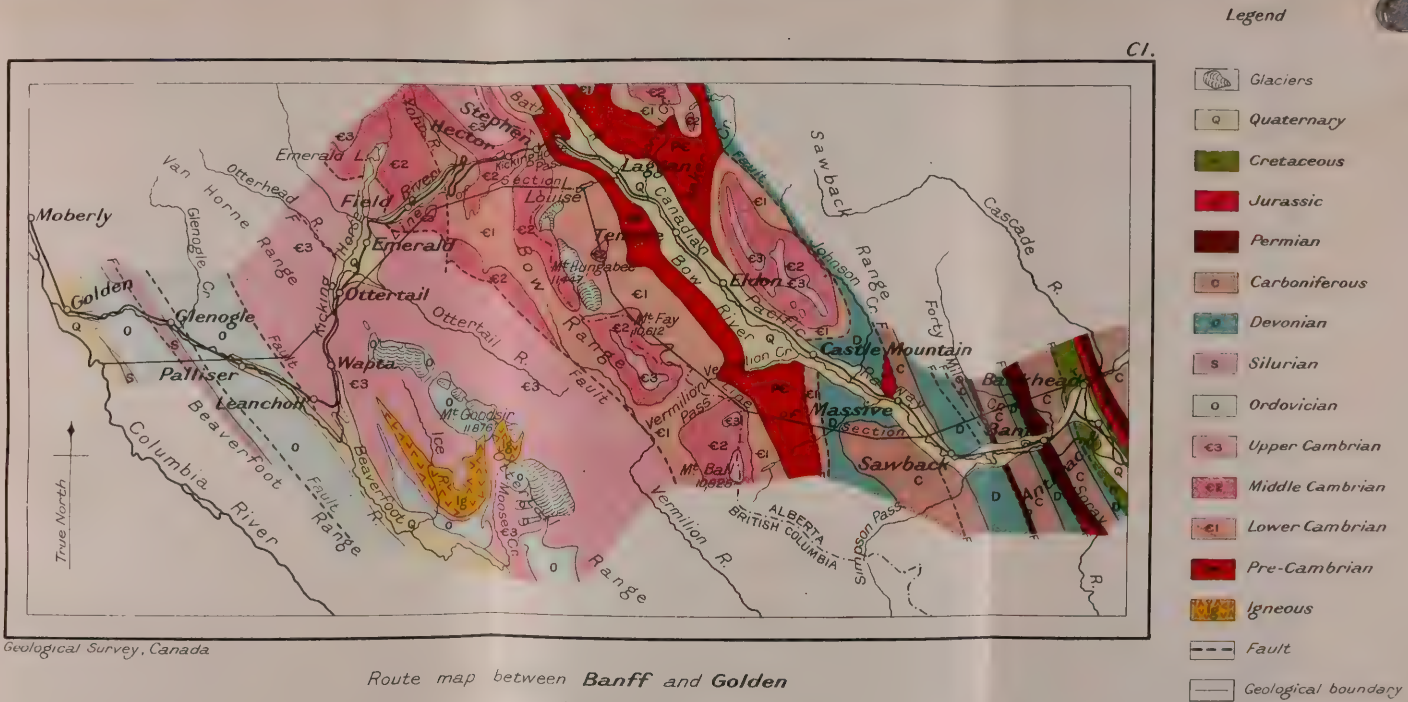
Geological Survey, Canada

Banff

Miles

Kilometres

C I.



Geological Survey, Canada

Route map between **Banff** and **Golden**

Miles
5 4 3 2 1 0 5 10 15 20

Kilometres
5 0 5 10 15 20 25 30

Miles and Kilometres.

northwest. The spring is not so strong as the upper one, and the temperature of the water is about 90° F. (32·2°C). A third or lower spring is situated farther to the northwest and about 50 feet (15 m.) above Bow river. The water is at a lower temperature than either of the upper two. Locally this spring is spoken of as the "Cave and Basin", because the spring rises into a cavern about 20 feet (6 m.) in diameter. By means of an underground channel it escapes to a natural basin formed in the calcareous tufa deposited. A second cave has been recently discovered a few yards farther up the slope. The interiors of these caves are coated with sulphur crystals. The Dominion Park Commission is erecting a substantial bath house at this spring for the accomodation of the public. Other warm springs are located in the bottom of Bow valley, about the Vermilion lakes. All of these springs are located in the Intermediate limestone (Devonian).

From the summit of Sulphur mountain can be seen the general monoclinal structure of this portion of the Rocky mountains. The successive ranges from the Cascade valley westwards represent westerly dipping fault blocks, which have become tilted along the east side. On the north side of Bow valley the Cascade, Vermilion Lake and Sawback ranges form distinct units, the same beds being repeated in each of these ranges.

83 m. 132·8 km. Leaving Banff station the railway follows along the broad swampy valley of the Bow, on the right of which is a series of three small lakes, called Vermilion lakes. The range to the right is the Vermilion Lake range, in which are exposed the westerly dipping Devonian, Carboniferous, Permian and Jurassic beds.

85 m. 136 km. This creek follows a fault line which divides the Vermilion Lake range from the Sawback range. This depression leads to Edith pass, beyond which can be seen Mt. Edith, which is made up of vertically dipping Lower Banff

Miles and Kilometres.

limestone. The steeply dipping beds on the west of this creek belong to the Sawback formation. This formation lies conformably under the Devonian Intermediate limestone, but the exact age is still doubtful, as no fossils have yet been found in it. Lithologically, a part of this series resembles the rocks of Silurian age in the Beaverfoot range to the west. To the south of the railway is the valley of Healy creek which extends to Simpson pass, and is the course followed en route to Mt. Assiniboine, the Matterhorn of the Canadian Rocky mountains. Bow river has here a meandering course, some of the lobes having been cut through, to form oxbow lakes.

88 m. 140·8 km. **Sawback.**—Alt. 4537 ft. (1,384 m.). West of Banff the railway crosses the strike of the formations in the Vermilion Lake and Sawback ranges, but at this point the valley of the Bow turns sharply to the northwest and follows along the strike of the formations as far as Laggan. The Carboniferous limestones dip at about 65° to the southwest, so that smooth cliffs formed along the bedding-planes are characteristic of the Sawback range. Mt. Hole-in-the-Wall, to the north of the station, is so called because it contains in its side a cavernous opening. This cave at its outer end is 50 feet (15 m.) in diameter, but becomes smaller behind as the floor rises. It is about 150 feet (46 m.) long and is situated, 1,500 feet (458 m.) above the railway, in the Lower Banff limestone. The position of the Lower and Upper Banff shales is always readily recognized by a depression on the surface.

93 m. 148·8 km. **Massive**—Alt. 4,600 ft. (1,402 m.). On the south side of Bow valley, Pilot mountain towers 5,000 feet (1,513 m.) above the railway. The base consists of Devonian limestone, and the peak is capped by Upper Carboniferous. From the Intermediate limestone in Fossil mountain, 10 miles northeast of Laggan, the following Upper Devonian fauna have been determined:—*Spirifer whitneyi* Hall; *Productella*

Miles and Kilometres.

hallana Walcott; *Stropheodonta demissa* (Conrad), *Schizophoria striatula* (Schlotheim), *Chenungensis var. arctostriatus* (Hall), *Phillipsastraea verrilli* Meek, *Syringopora cf. perelegans* Billings, and other Devonian species.

A few yards beyond the west end of the siding, the railway cuts through a down-faulted block of dark brown Fernie shales containing ammonites, which indicate that they are Jurassic in age.

96·2 m.
153·9 km. The upper part of Johnson creek separates Sawback range from Castle Mountain range. It follows in a fault valley. Four miles from its mouth the stream has been diverted to the south by the down-faulted block of Jurassic shales referred to above. From this point there is an excellent view of Castle mountain with its perpendicular cliffs and broad amphitheatre behind.

99 m.
158·4 km. **Castle**—Alt. 4,660 ft. (1,420 m.), is situated at the base of Castle mountain. West of the station the railway follows along the base of this mountain for over 10 miles (16·1 km.). The eastern end of the mountain is terminated by a large pinnacle which, from the railway, resembles the ruins of a massive castle; hence the name. The accompanying illustration shows the character of the rock in Castle mountain. The upper slopes are Cambrian. It is capped by the thin-bedded red-weathering limestones and shales of the Bosworth formation (Upper Cambrian). The perpendicular cliffs at the top represent the Eldon formation. This is the type locality and this formation has a measured thickness of 2,728 feet (832 m.). The Stephen formation is about 600 feet (183 m.) thick, and forms a very flat talus-covered slope, while the Cathedral formation below is about 1,500 feet (458 m.) thick and forms a precipitous slope. These three formations are Middle Cambrian in age. The Lower Cambrian beds are largely quartzitic and form brush-covered, irregular slopes.

Miles and Kilometres.

Castle was an active town with about 1,500 people in 1884-86, but is now deserted. The "boom" was caused by the discovery of copper prospects in Copper mountain directly south of the station on the opposite side of the valley. Mining proved a failure. And there is now only one of the old timers, James Smith, living here.

There are numerous foundations on this flat, but most of the buildings have been burned or torn down.

100 m.
160 km.

The Dominion government is building an automobile road across the Rocky mountains from Calgary to Golden. The road here crosses the railway and Bow river; it follows up Vermilion creek to the south, over the Vermilion Pass, and down Vermilion river to the Kootenay, thence into the Columbia valley and down to Golden. The road is nearly completed up to the pass, which, with an elevation of 5,264 feet (1,605 m.), is the lowest pass in this part of the Rocky mountains. To the east of Vermilion Pass is seen the craggy cliffs of Storm mountain (altitude 10,309 feet) in the Middle and Lower Cambrian formations. The lower rounded ridges to the east are formed of Pre-Cambrian shales. The contact, apparently slightly unconformable, is exposed at the eastern base of Storm mountain.

105·5 m.
170·4 km.

Eldon—Alt. 4,817 ft. (1, 468 m.). The broadly rounded Bow valley is underlain by the softer Pre-Cambrian shales included in the Hector and Corral formations. The Pre-Cambrian beds floor the Bow valley and the lower slopes up to Kicking Horse pass, and to the head waters of Bow river. This series has been called Pre-Cambrian by Walcott [**4**], because the beds are largely unfossiliferous and underlie the Olenellus zone of the Lower Cambrian. These beds represent a portion of the Bow river group, defined by McConnell [**5**]. A few brachiopod-like fossils were found by the writer in a layer of Hector shale at the base of Storm mountain.

Miles and Kilometres.

112 m. Between this point and Laggan one has the
179·2 km. best view of the valley of Ten Peaks, also Paradise valley and the majestic peaks of the Bow range. The peaks which stand out in prominence are a few of the Ten Peaks, including Mt. Fay and Mt. Deltaform (11,225 ft.—3,421 m.); also Mt. Temple (11,626 ft.—3,544 m.), the highest peak in the range visible from the railway. On approaching Laggan, Fairview, Aberdeen, Whyte, and Victoria become visible.

113·9 m. The first and lowest exposure of Pre-Cambrian
182·2 km. occurs to the right of the railway. It is a coarse pebbly sandstone containing pink felspar.

115 m. **Laggan**—Alt. 5,037 ft. (1,535 m.). From
184 km. this point, type localities for Cambrian and Pre-Cambrian formations will be visited. A driveway and a railway lead up to Lake Louise and the Chalet. This lake is situated over 600 feet (183 m.) above Bow river, at the front of a large cirque which is occupied at the south end by Victoria and Lefroy glaciers. The lake is surrounded by Lower Cambrian quartzites of which the St. Piran formation stands out in prominence and forms precipitous cliffs. The contact between the Lower Cambrian quartzites and the Middle Cambrian limestones is well shown in the lofty mountains about this valley. The illustration on page 178 shows the Mitre with Mt. Lefroy on the right, Mt. Aberdeen on the left, and a portion of the Lefroy glacier with a well defined bergschrund. The cliffs are Lower Cambrian, and the Mitre is capped with the Cathedral limestone of the Middle Cambrian. The pass to the right is called the Death Trap on account of its dangerous position.

A visit will be made to Valley of the Ten Peaks, and the mouth of Paradise valley will be passed on the way. Both are typically hanging glacial valleys with glaciers at their upper termini. In the former the valley is

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surrounded by ten gigantic peaks each of which shows the Lower and Middle Cambrian formations. Moraine lake lies in this basin between a large moraine and the Wenchemna glacier. Mt. Temple (11,626 feet), (3,543·6 m.), the highest in this part of the Rocky mountains, stands between these two valleys. The talus slope shown in the illustration on page 175 shows the position of the contact between the Pre-Cambrian and the Cambrian. The Middle Cambrian begins at the change in slope in the cliffs on the left, and the peak is capped by Upper Cambrian thin-bedded limestones of the Bosworth formation.

Leaving Laggan station, a good exposure of Pre-Cambrian slates and shales wiil be visited within 200 yards (183 m.) of the west end of the railway yards. The illustration on page 173 shows the conformable contact between the Pre-Cambrian shales of the Hector formation and the Lower Cambrian quartzites. This contact is exposed in the south end of the ridge separating the Bow valley from the much smaller valley of Bath creek.

116 m. 185·6 km. One mile west of Laggan the railway leaves the Bow river and follows up Bath creek to the summit. Bow river continues toward the northwest, to its source in Bow lakes, 20 miles (32·2 km.) up the valley. The stream is enlarged by water from Hector lake. Mt. Hector (11,125 feet) (3,391 m.), with its castellated cliffs of Lower and Middle Cambrian formations, can be seen from the railway to the right of Bow valley.

121·5 m. 194·4 km. In a quarry on the right of the railway there is a good exposure of Pre-Cambrian slates, in fresh condition. These shales and slates are transported to Exshaw, where they are used in the manufacture of cement. The purplish and drab color of these rocks is characteristic of the formation.

122 m. 195·2 km. Looking ahead to the right can be seen the perpendicular cliffs of Mt. Daly formed in Middle Cambrian limestones, with a typical

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cliff glacier, a fragment of the large Daly glacier, on its eastern flank.

A few yards west of the crossing of Bath creek there is a good exposure of Cambrian basal conglomerate. It encloses fragments of the underlying slate, but the exact contact with the Pre-Cambrian is not visible along the railway.

122·2 m.
195·5 km. **Kicking Horse Pass** (The Great Divide)—Alt. 5329 ft. (1,625 m.). This is the continental divide. The pass, discovered by Sir James Hector in 1876, is a saddle-like depression about two miles broad carved out by the ice. The grade from the pass to the west into Kicking Horse valley is very much steeper than it is to the east into the Bow valley.

To the right of the pass is Mt. Bosworth in which there is exposed nearly 9000 feet (2743 m.) of Lower, Middle, and Upper Cambrian strata. The Bosworth section was examined by Walcott (**5**) in 1908, this being the first attempt to subdivide the Cambrian of the Canadian Rocky mountains into formations. From this point it will be seen that the structure in the western slope of the Rocky mountains represents the western limb of a monocline; whereas the Cambrian basal conglomerate is exposed near the divide, the rocks are Ordovician and Silurian in age in the last range to the west.

125 m.
200 km. **Hector**—Alt. 5,207 ft. (1,587 m.). The stream entering the lake at this point is Cataract brook. It drains Lake O'Hara and Lake McArthur, and glaciers on Mts. Victoria, Huber, Hungabee, Odaray, Cathedral and Stephen. Wapta lake at the right of the railway is the main gathering basin for the headwaters of Kicking Horse river. Below the end of the lake the river has cut a canyon through the Middle and part of the Lower Cambrian formations.

128 m.
204·8 km. From this point there is an excellent view of Yoho valley, a glacial U-shaped depression, which heads in the Yoho glacier. The valley

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is cut through Lower and Middle Cambrian strata. At Takakkaw falls, 1,248 feet (380 m.) high, the water cascades over Middle Cambrian limestone. The same formation causes the Twin falls, farther north in the valley, but the fall is not as great.

129 m. **Upper end of No. 1 Tunnel.** Between the
206·4 km. Pass and
131·1 m. **Lower end of No. 2 tunnel.** Field, a dis-
209·7 km. tance of about
eight miles (12·9 km.), there is a difference in elevation of 1,160 feet (353·5 m.), of which 900 feet (274 m.) occurs within four miles (6·4 km.). To overcome this steep grade the Canadian Pacific railway has constructed two spiral tunnels. The upper one (No. 1), 3,200 feet (982·4 m.) long, is in Lower Cambrian quartzites in the base of Cathedral mountain. The lower one (No. 2), 2,900 feet (884 m.) long, is in Middle Cambrian limestones in the base of Mt. Ogden. There is a difference of 60 feet (18·3 m.) between the rails at the ends of the tunnel, in both No. 1 and No. 2. The average grade is now 2·2 per cent, whereas the grade of the old road, now used as a wagon road, is 4·4 per cent.

Before entering No. 2 tunnel, the glacier-shaped Kicking horse valley is seen, with its broad aggraded valley floor. On the left of the valley is Mt. Stephen (10,485 ft.—3,196 m.), and on the right is Mt. Field (8,645 ft.—2,636 m.).

132·5 m. About one mile (1·6 km.) west of Cathedral
211·2 km. station the railway passes through a short tunnel in Lower Cambrian quartzites. Between this tunnel and the wagon road there is a normal fault with about 3,000 feet (921 m.) displacement. Mt. Stephen is on the downthrow side, so that the Lower Cambrian quartzites in the Cathedral mountain come against the Eldon formation, at the top of the Middle Cambrian, in Mt. Stephen. This break has been called the Stephen-Cathedral fault.

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From this point there is an excellent view of Mt. Stephen. The base of this mountain is Lower Cambrian and it is capped by Bosworth formation (Upper Cambrian). The Cathedral formation extends to the top of the great North shoulder.

The Monarch mine is situated in Mt. Stephen about 1,000 feet (305 m.) above the railway in the Cathedral formation. The ore, consisting of lead and zinc sulphides, is a replacement deposit along a major and several minor fissures. A concentrating mill, on the left of the railway, has been recently constructed and is separating about 80 tons of ore per day.

The second short tunnel passes through the St. Piran quartzite in the shoulder of Mt. Stephen. The railway follows along the slope of the mountain, gradually approaching the level of the valley floor. At Field it is only 10 feet (3 m.) above the river.

137 m. 219·4 km. **Field**—Alt. 4,064 ft. (1,239 m.). This railway divisional point is the gateway to Yoho valley, Emerald lake and Ice River valley.

The famous trilobite fossil bed outcrops in the Ogygopsis shale about 2,600 feet (793 m.) above the railway on Mt. Stephen. Walcott [**6**] has determined 32 species of trilobita and brachiopoda from this lentile of shale. This shale belongs to the Stephen formation (Middle Cambrian.).

Another fossil bed recently discovered by Walcott occurs in the west slope of Mt. Field, in the "Burgess shale," which also belongs to the Stephen formation. This fossil bed is reached by Burgess pass and is shown in an illustration on page 177. From this shale Walcott [**7**] has determined trilobita, brachiopoda, merostomata, malacostraca, annelids, holothurians and medusae.

West of Field the beds dip more steeply to the west. A normal fault with the downthrow on the west side, passes between Mt.

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Stephen and Mt. Dennis. This is called the Stephen-Dennis fault.

Two miles (3·2 km.) west of Field the Kicking Horse river becomes a narrow channel and in one place passes under a natural bridge formed in the Upper Cambrian shales and slates.

3·5 m.
5·6 km.
from Field.

Emerald—Alt. 3,895 ft. (1,188 m.). There are over 300 feet (91·5 m.) of Pleistocene lacustrine gravels along the sides of the Kicking Horse valley. The Canadian Pacific Railway Company has erected a gravel-washing plant at the station, the gravel being used for ballast after the clayey material has been washed out.

On the north side of the valley five distinct terraces can be recognized in these gravels along the valleys of Emerald creek and the Amiskwa river.

For the next four miles (6·4 km.) Kicking Horse river has a broad alluvial flood plain, nearly two miles wide in places.

Looking ahead to the right of the railway red-capped peaks and ridges in the Van Horne range are seen. These red-weathering shales, slates, metargillites and phyllites belong to the Chancellor formation of the Upper Cambrian, and overlie those beds exposed on the top of Mt. Bosworth at the divide.

On the south side of the railway in the Ottertail range, these shales and slates are overlain by the massive Ottertail limestone which forms precipitous slopes. The accompanying figure shows a gentle slope on the Chancellor shales and a very steep slope in the Ottertail limestone. Some of the peaks in this range are capped by Goodsir shale, the lowest formation in the Ordovician. The very sharp contact exposed in Mt. Goodsir in the Ice River valley, between the Cambrian, represented by the Ottertail limestone and the Ordovician represented by the Goodsir shales, is shown in another illustration page 180 (**8**). The fauna in those

Miles and Kilometres.

shales determine the age of the beds. Mt. Goodsir (11,676 ft.; 3,565 m.) is the highest in the Rocky mountains near the railway. A glimpse of this peak can be seen on the left of the railway at about five miles (8 km.).

Ottertail escarpment, showing Chancellor formation forming talus-covered, undulating surface; Ottertail limestone in cliffs; and Goodsir shales on gradual slopes.

8·2 m. 13·1 km. **Ottertail**—Alt. 3,696 ft. (1,127 m.). For some distance on either side of the station the railway cuts through highly sheared Chancellor shales and slates which are here characterized by their silken lustre and purplish gray color. The river now flows almost due south at the bases of Mt. Hurd and Mt. Vaux.

15 m. 24 km. The railway turns sharply through an angle of 120 degrees to the northwest around the end of a ridge of Upper Cambrian limestone. The river continues to the south for about two miles (3·2 km.) and then makes a similar sharp bend to the northwest. At this bend is Wapta falls, formed in the highly sheared, steeply tilted Upper Cambrian slates. The Beaverfoot valley extends to the left of the railway, and was the course followed by Kicking Horse river in pre-Glacial time. The stream course was diverted largely by morainal obstructions.

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17 m. 27·2 km. **Leanchoil**—Alt. 3,681 ft. (1,123 m.). Looking east along the railway, the Ottertail range lies in the background. Chancellor peak (10,751 feet, 3,276·8 m.) is especially prominent. Behind this ridge lies Ice River valley, in which is exposed the only igneous complex in this portion of the Rocky mountains. It covers about 12 square miles, has the form of an asymmetrical laccolith, and is alkaline in composition. This is one of the few localities in which sodalite is found in considerable quantities.

Between the second and third peaks to the left of Chancellor peak, the contact between the dark coloured igneous rock, (an ijolite), and the gray limestone can be seen from this point.

22·9 m. 36·6 km. **Palliser**—Alt. 3,283 ft. (1,001 m.). The highly sheared Goodsir shales outcrop at many places on either side of the railway. North of the station is a fault-line scarp on the shoulder Mt. Hunter. The up-throw has been on the northeast side so that the Upper Cambrian beds adjoin the faulted edges of the Lower Ordovician shales.

The glacial gravels are over 200 feet (61 m.) thick, and are frequently well terraced on both sides of Kicking Horse valley.

West of this point the valley narrows, and a canyon has been cut through steeply tilted Ordovician and Silurian beds in the Beaverfoot range.

28·4 m. 45·4 km. **Glenogle**—Alt. 2,991 ft. (911·5 m.). The best exposure of the black, fissile, Graptolite shales will be seen in the first small creek at the west end of the railway siding. This fauna is especially abundant in one thin layer of this formation. Throughout the remainder of the canyon the structure is complicated by faults and overturned folds. The Silurian beds are recognized as white quartzites and gray massive dolomitic limestones. This formation is highly fossiliferous in certain horizons.

Miles and Kilometres.

About one mile west of Glenogle there is a mineral spring in the Silurian dolomitic limestones. A yellowish calcareous deposit thickly coats the rock over which the water flows. Another spring rich in calcareous material, occurs about one mile farther down to the right of the railway. Some of the mineral spring water from this canyon has been tested and found to be rather strongly radioactive.

About half a mile east of Golden the valley of Kicking Horse river opens out into the Columbia valley. In the railway cut at this point there is a good exposure showing the gravels of the Columbia lying against the very steep side of the old valley along the western base of the Beaverfoot range. These stratified gravels extend at least 350 feet (107·5 m.) above the river.

35·6 m. 572 km. **Golden**—Alt. 2,580 ft. (786 m.). Kicking Horse river joins the Columbia river at this point.

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ANNOTATED GUIDE.

(Golden to Savona.)

BY

REGINALD A. DALY.

Miles and Kilometres.

35·3 m. 56·8 km. **Golden**—Alt. 2,578 ft. (786 m.). The train here enters a typical section of the Rocky Mountain trench, a through-going Cordilleran feature of a length hardly to be matched in any other mountain chain. About 100 miles (160 km.) above Golden is the source of the Columbia river, which, except for a short distance, occupies the main trench as far as the beginning of its "Big Bend", 87 miles (140 km.) below Golden.

The town overlies Ordovician shales; the long bastion-like escarpment of the Dogtooth range (Purcell Mountain system) across the valley is composed of the uppermost slates, schists, and quartzites of the Beltian series. The trench is, in fact, here located on a master longitudinal fault of a throw at least equivalent to the entire thickness of the Cambrian group (5700 m.). The fault plane runs close to the lower cliffs of the Dogtooth mountains. It has clearly located the trench, which, however, has been specially widened by erosion on the softer Paleozoic rocks ranging east of the great break. The fault probably dates from the Laramide (post-Laramie and pre-Eocene) revolution. The colossal denudation represented in the destruction of the uplifted Purcell block must have consumed much of Tertiary time. What part of the period was concerned with the excavation of the visible trough it is still impossible to say. The work was done in stages. In the later Tertiary the trench has been increased to widths of three to six miles (5 to 10 km.), a past-mature river

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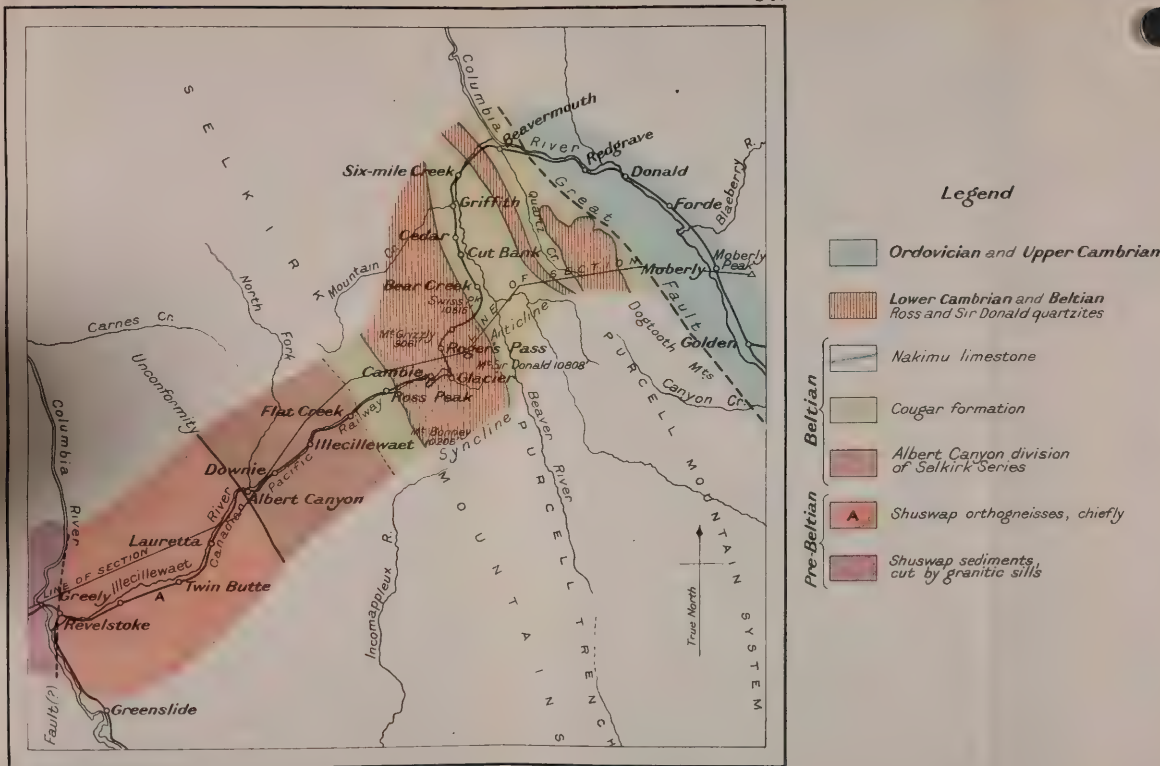

Geological Survey, Canada.

Route map between **Golden** and **Revelstoke**

Miles and Kilometres.

valley of first magnitude. Probably during the late Pliocene the region was uplifted and a narrower trough sunk in the old valley floor. Remnants of that floor are visible in the trench at elevations of 650 to 1,000 feet (200 to 300 m.) or more above the river. The bed-rock form has been seriously affected by Glacial erosion and deeply covered with drift, into which the Columbia has cut, with the development of terraces and a broad flood-plain.

The Pleistocene deposits are so thick and continuous in the trench that bed-rock crops out at the railway only twice between Golden and the 53rd mile-post, a distance of 28 kilometres. Practically as far as the observer at Golden can see on the southwest side of the trench, both north and south of the town, the rocks are silicious sediments of latest Beltian age. On the northeast side, the heights are chiefly composed of the Silurian (Moberly Peak) or Ordovician formations. After leaving Golden the first important exposure of rock at the railway track is on the right, at the crossing of Blaeberry river (45 mls.), where the Goodsir (Ordovician) shales are dipping at an angle of about 55° to the northeast. These, like all the other Paleozoic strata seen in the trench, are more or less crumpled and cleaved, indicating great disorder in this broad band followed by the trench. On the whole, however, the Cordilleran strike is preserved here, as it is all across the Middle ranges as far as Albert Canyon.

Purcell Mountain System.—The rugged wall on the west side of the trench is the northeasterly limit of the group of the high peaks here included in the Purcell system. As shown in the accompanying structure section, the rocks in this escarpment form the northeastern limb of a wrinkled syncline adjoining a well developed anticline along which the valley of Quartz creek has been excavated. The compound syncline has suffered intense glacial erosion, producing abundant alpine horns;

Miles and Kilometres.

hence the appropriate name, Dogtooth mountains, for this division of the Purcells, situated between Quartz creek and the Columbia. A narrower, tightly compressed syncline forms the adjacent lower and less rugged range, called the Prairie Hills. That mountain group overlooks the broad Beaver River trough which, between Six Mile Creek (68·0 mls.) and a point many miles south of Beaver Creek (78·0 mls.), is an anticlinal valley excavated in the relatively friable rocks of the Cougar formation.

The Purcell mountain system is thus essentially a mass of Beltian strata folded with comparative regularity. The Cordilleran strike (here N. 30° W.) is generally well preserved throughout the whole area covered in this part of the Purcell system, as it is in the much broader section mapped at the International Boundary, far to the south. However, the folds show local disorder; they were accompanied by subordinate fractures and, where closely appressed, by mashing and by the development of slaty cleavage.

Three kilometres beyond Donald, soon after crossing the river, the railway enters a long series of rock cuts, where the river leaves the main trench, and is cutting a long canyon across the folded and mashed Paleozoics. On the right bank of the river, for a distance of many kilometres, is a mountain block separated from its structural equivalent, the Dogtooth range, by a late Glacial diversion of the river from the broad trench on the east. The Paleozoic shales and limestones, standing at high angles, can be seen in the walls of the canyon. Near the tunnel marked as 54·6 miles from Field, fossils of late Upper Cambrian age, including an *Illenurus* and a genus like *Dicellocephalus*, have been found in abundant calcareous nodules formed in shale and impure limestone.

The strata grow more and moie disordered until the great Trench fault is reached, at a

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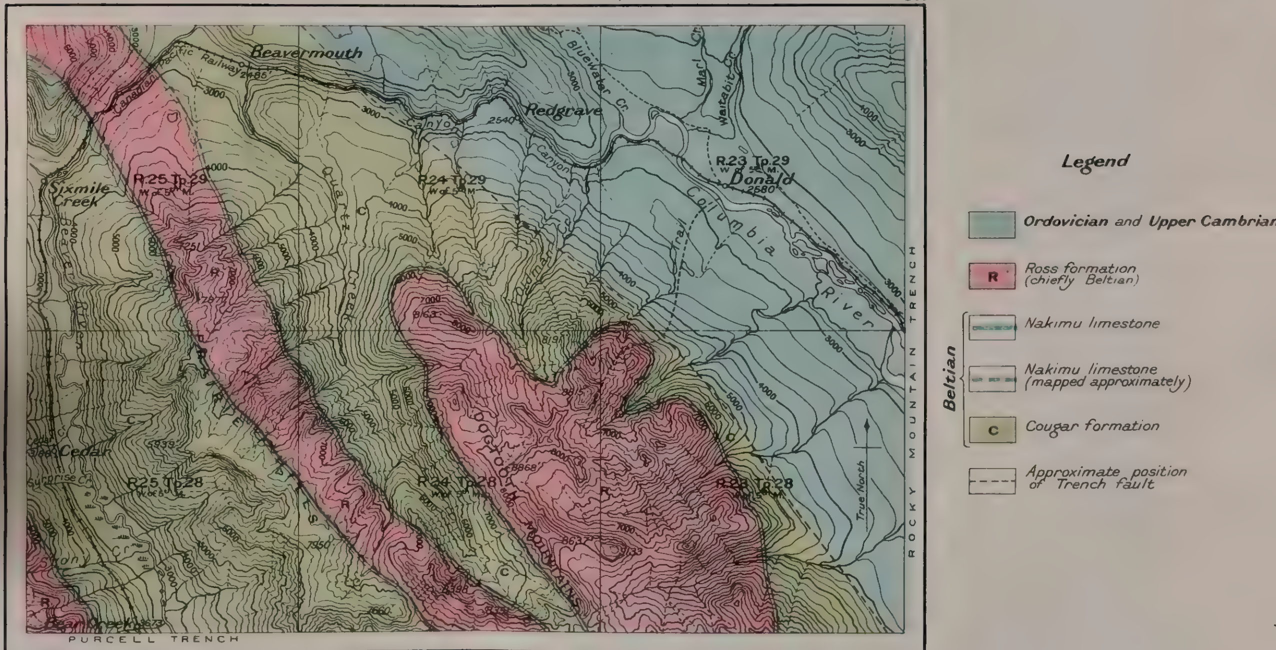

Geological Survey, Canada.

Prairie Hills and Dogtooth Mountains

Miles

1 ½ 0 5 10

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5 4 3 2 1 0 5 10

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point about 3 kilometres east of Beavermouth station. There the Paleozoic shales and limestones abruptly cease and the train runs over the quartzites, slates, and schists of the Beltian Cougar formation. An exceptionally thick and massive quartzitic member of this formation soon appears in bold bluffs on the left; the same band of rock crosses the river at Beavermouth and continues on a N. 30° W. strike into the mountain to the right of the Columbia.

63·2 m. 101·7 km. **Beavermouth**—Alt. 2,430 ft. (741 m.), is situated at the confluence of Quartz creek and the Columbia river. The creek represents a case of stream diversion. Its former course lay to the eastward of the high mass of quartzite southeast of the station. Across that rock it had cut a narrow canyon about 1·2 kilometres in length and about 75 metres in average depth. Its floor is nearly 300 m. above the Columbia. Specially rapid (Glacial?) erosion on a band of fissile schists paralleling this quartzite on the southwest caused the diversion of the creek to its present course. The high-level canyon is now nearly dry and is open at both ends. Placer mining for gold has been carried on for some years along Quartz creek.

Two kilometres beyond Beavermouth the railway turns sharply away from the Columbia into the transverse valley of Beaver river, where the Prairie Hills syncline is exposed in a long succession of deep rock-cuts. The syncline is tightly closed. The first outcrops, seen where the railway first meets the Beaver, are cleaved quartzites and slates of the Cougar formation. These are often crumpled in detail but the general dip is about 80° to the southwest. At the 65·6-mile point the overlying Nakimu limestone, here reduced by shearing-out to a single vertical bed a few metres thick, is

65·8 m. found. Close by is **The Gateway,** where the

105·8 km. vertical Ross quartzites, forming the heart of the syncline, are well exposed. This is the only section where one has a good opportunity of seeing this important formation close

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at hand. Its habit is somewhat abnormal on account of unusually intense cleaving under tangential stress. Where seen outside this Prairie Hills syncline, the Ross quartzite is more massive. All or nearly all of the formation here exposed is of Beltian age; the younger, Lower Cambrian beds may not appear at this low level in the fold.

The southwestern limb of the syncline becomes identifiable at a point nearly 2 kilometres beyond the bridge over the river, where the Nakimu limestone with steep northeasterly dip crosses the railway. The train then runs over the Cougar formation with similar dips until, at a point about 2 kilometres beyond Sixmile Creek station, the dip becomes vertical or disordered. At that locality is the axis of the Beaver River anticline, trending N. 30° W.

Purcell Trench—As the train slowly climbs the steep grade to Bear Creek station, an excellent view of the Purcell Trench in its northern, relatively narrow development, is obtained. With remarkable straightness this primary feature of the Cordillera continues 40 kilometres S.S.E., to the head of the Beaver river and then down the Duncan to Duncan lake and the long Kootenay lake. The trench ends at Bonner's Ferry, Idaho, where it is entered by the transverse valley of the Upper Kootenay river. The total length of the trench is about 350 kilometres. West of it is the Selkirk Mountain system; east of it the group of ranges to which the inclusive name, Purcell system, has recently been applied.

Here in its northern part the trench is an erosion trough opened on the axis of a broad anticline which has been demonstrated for a distance of 30 kilometres and probably extends still farther south. At the International Boundary, the trench is considerably broader and is an erosion trough located on a longitudinal fault of the first order. Elsewhere, the origin of this depression has not been determined.

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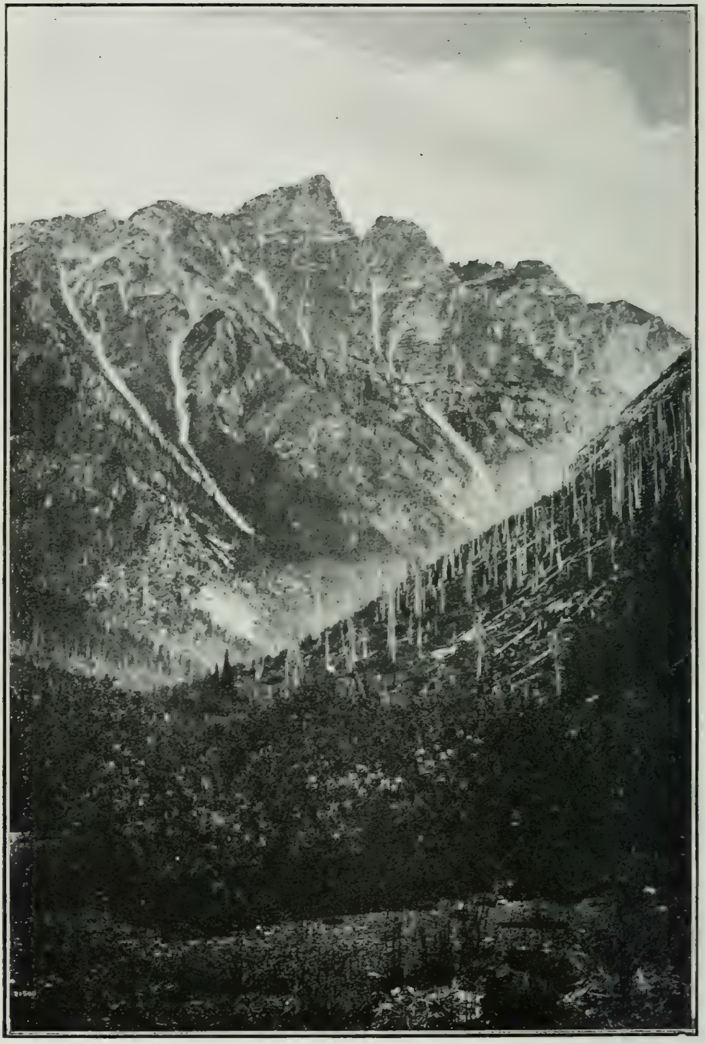
The trench has been deepened and widened by Glacial erosion, with the resulting development of hanging valleys. The railway crosses several of these, in which the streams have already cut deep gorges in the schists and fissile quartzites. The walls of the trench, especially on the southwest side, are ornamented with scores of cirques, many being still deepened by living glaciers.

Excepting a few of the highest peaks, the entire mountain wall visible on the Purcell side of the trench is composed of the thick Cougar formation dipping steeply to the E.N.E. All the rocks in the lower slopes of the Selkirk wall belong to the same formation, here dipping steeply under the Nakimu limestone and the massive Ross quartzite, of which most of the highest peaks of the Selkirks are constituted.

78·0 m. 125·5 km. **Bear Creek station**—Alt. 3,663 ft. (1116 m.). Below this point, near the confluence of Bear creek and Beaver river, the railway company is about to pierce a two-track tunnel, 7·5 kilometres (4·6 miles) in length. It will cross the main divide of the Selkirks and emerge at the railway loop near Glacier. One of the main objects of this boring is to cut out of the line of traffic the long chain of yet more expensive snowsheds now necessary between Bear Creek and Rogers Pass stations.

Beyond Bear Creek station the line turns up the creek and crosses the summit syncline of the Selkirk range. The upper beds of the Cougar formation and the Nakimu limestone are quickly traversed. On the left, above the forest of the canyon bottom, can be seen the thick rusty quartzites of the Ross formation, overlain by the gray, likewise massive, Sir Donald quartzite. The impressive horn of Mount Macdonald is composed of this youngest member of the Selkirk series, there forming an open, subsidiary syncline, which is continued into the still invisible peaks of Mt. Tupper on the north.



Mt. Tupper from Rogers Pass. Slopes underlain by Sir Donald quartzite.

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As the train emerges from the last snow-shed, the western limb of the sharp anticline, shown in the general structure section, may be seen on the left.

84·1 m. 135·4 km. **Rogers Pass**—Alt. 4,302 ft (1,311 m.). This station is situated on the axis of the main Selkirk syncline. The fold is here broken and faulted but the flat-lying beds of the axis can be seen, in clear weather, on the slopes to the north-northwest. The eastern limb is clearly apparent but the western limb is best exposed in the upper canyon of Bear creek. An oblique view of the subsidiary folds already passed over may be had toward the northeast, in the crags of Mt. Tupper.

The railway follows the axis of the main
87·3 m. syncline to **Glacier**—Alt. 4,086 ft. (1,245 m.).
140·5 km. Here the Illecillewaet and Asulkan glaciers are reached by good trails. The former drains the Illecillewaet snowfield (25 square km. in area) at its northern end, while the Geikie glacier drains it at the south. The Asulkan glacier is one of the several sheets heading on the rugged ridge culminating in Mt. Bonney. All of the glaciers are rapidly retreating, as illustrated in the accompanying figures.

The special map and section of this region, makes a detailed description of the local geology superfluous, but some remarks may be helpful.

The noble peak of Mount Sir Donald (10,808 ft.; 3,292 m.) to the southeast is composed of the Sir Donald quartzite, well jointed in sheets which from a distance deceptively resemble individual strata. The true dip of the quartzitic sandstone is to the E.N.E., at angles varying from 60° on the western slope to 15° or less at the eastern foot of the horn. Mount Sir Donald is, in fact, a remnant of a long,

Illecillewaet glacier in August, 1911. Photograph by H. Ries.

Illecillewaet glacier in August, 1912. Comparison with preceding figure shows recession of the ice-front during the year preceding. Photograph by H. Ries.

narrow, synclinal wrinkle adjoining the great Beaver River (Purcell trench) anticline. A subsidiary anticlinal axis, paralleling this syncline on the southwest, runs nearly through the crest of Eagle and Avalanche mountains and is probably coincident with the one just

Mt. Sir Donald from Eagle mountain; Mt. Uto in foreground. Photograph by Howard Palmer.

west of Mt. Macdonald summit. The western limb of this fold is also the western limb of the syncline followed by the railway from Rogers Pass to Glacier.

Another local anticline in the quartzite is well exposed near tree-line on Mt. Cheops and is continued across the Illecillewaet into Mt. Abbot. Some faults and numerous small slips, parallel to the general strike, have complicated the structure between Mt. Sir Donald and Cougar creek. On this account, and because of the close similarity of the Sir Donald

and Ross quartzites, it has proved very difficult to map the exact contacts of these two formations. Nearly all the cliffs from the hotel seem to be composed of the Sir Donald formation. In spite of local complications, the upper valley of the Illecillewaet river, including the névé region, is to be considered as lying in the axis of the main Selkirk syncline. This view is substantiated by the easterly dip of the Nakimu limestone, exceptionally well exposed on Cougar mountain and Ross peak.

The character of the Sir Donald formation may be studied in the many large blocks strewing the floors of the valleys above the hotel. The essential similarities of the quartzitic sandstone, grit, and occasional conglomerate to the different phases of the St. Piran formation in the Rocky mountains (Lake Louise and elsewhere), are so many and so special that these formations have been correlated with much confidence. A general stratigraphic comparison, has in fact, referred the Sir Donald and the upper beds of the likewise unfossiliferous Ross quartzite to the Lower Cambrian.

A highly characteristic feature of all these formations is the abundance of bluish, opalescent quartz grains and pebbles, which are also found at many horizons in the Cougar formation, The source of this quartz is to be found in the coarse orthogneisses and pegmatites of the Shuswap terrane bordering the Selkirks on the west. The sometimes abundant feldspar grains in these sediments are microcline, microperthite, orthoclase, and acid plagioclases —all largely derived from the same source. Mineralogical composition, general stratigraphy, and field habit indicate that the Selkirk series represent the northern continuation of the thick Belt series of Montana and Idaho.

In the Selkirk mountains, there can be no doubt as to the conformity of the rocks here referred to the Lower Cambrian with the older, enormously thick mass of strata (Beltian system) to be seen between Ross Peak and Albert Canyon stations.

Miles and Kilometres.

From Observation point on Mt. Abbot one obtains an extended view in the heart of the Selkirk synclinorium. On the right and in front are the structural features so far noted. On the left, at the eastern end of Cougar mountain the Nakimu limestone is conspicuous in a steep rock-slope bare of vegetation. Farther west, to the limit of vision, the mountains are composed of the older Beltian strata, dipping monoclinally to the northeastward.

Leaving Glacier, the train descends to the "Loop", where the Selkirk tunnel will emerge at its western end. On the left a brief view is obtained of the Bonney glacier; on the right, a closer view of the gray Nakimu limestone on the western slope of the Cougar valley. One kilometre beyond the Cougar watertank, the limestone can be seen, continuing on the regional strike over the col between Green peak and Ross peak. The Caves of Nakimu (Caves of Cheops) are irregular tunnels occupied by Cougar creek in a subterannean part of its course along the limestone. Here we have the most westerly outcrop of this invaluable guide to the stratigraphy of the Selkirks.

For the next 5 kilometres the train runs over the Cougar formation, here distinctly more massive, homogeneous, and quartzitic than on the eastern slope of the Selkirk range. To right and left, heavy beds of white quartzite, interrupting the dominant, gray and rusty strata, can be seen. A narrow synclinal wrinkle affects the
95 m. general monocline about 1 kilometre west of **Ross
153 km. Peak station** and, in good light, can be discerned in the high bluff on the left.

Four kilometres beyond Ross Peak station (94·2 mls.), the quartzitic Glacier division of the Selkirk series conformably overlies the dark-coloured metargillites of the Albert Canyon division. The position of the contact between
98 m. these two contrasted formations can be seen
158 km. on the slope southeast of **Flat Creek station.**

From this contact, crossing the railway near

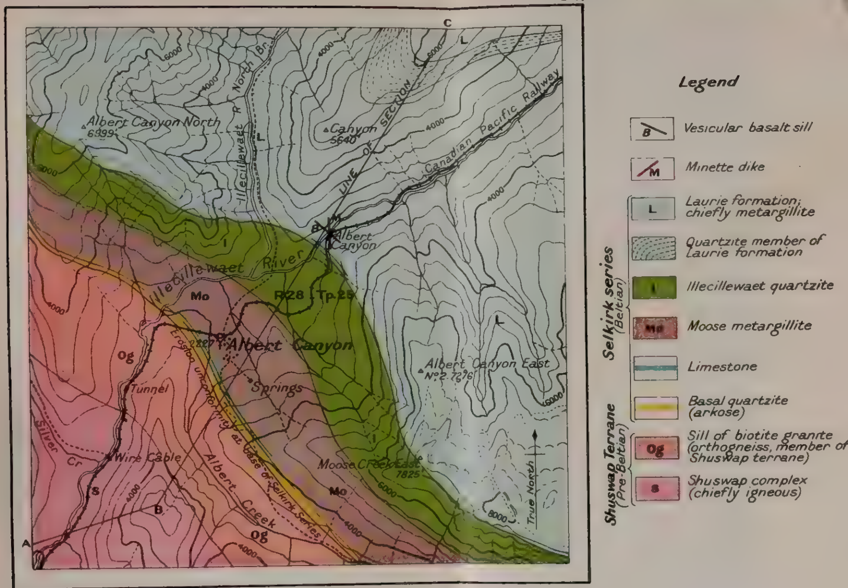
Miles and Kilometres.

the 97th mile-post, to the Illecillewaet gorge, a distance of 10 miles (16 km.), the route crosses the northeasterly dipping beds grouped under the name, Laurie formation (See p. 134). Its apparent thickness is extremely great and, as yet, no evidence of large-scale duplication of strata has been discovered. Dawson considered that these beds have a synclinal structure, (G.M. Dawson, Bull. Geol. Soc. America, Vol. 2, 1891, p. 174), but detailed work has shown that they form a monocline accidented by rare, narrow strike-zones of crumpling. The most important of such zones is clearly visible from **Laurie station** (100·5 m.) in the long gulch due northwest of that point. Allowing liberally for all such evidences of repetition, the Laurie formation is still to be credited with a minimum thickness of over 4,500 metres.

From Flat creek to Illecillewaet (102·8 mls.; 165·4 km.) the dip averages about 50° to the N.E. The dark-gray to black, often highly carbonaceous and pyritous metargillites are well exposed in occasional long railway cuts. They are remarkably homogeneous for a nearly continuous exposure of 500 to 1,000 metres at a time. The principal variations consist in the alternation of more massive phases with the dominant fissile metargillite; rare, thin beds of carbonaceous limestone are found but the quartzitic interbeds noted in the columnar section do not crop out at the railway (see p. 134). Though the metargillite usually has a phyllitic appearance, this is not due to dynamic metamorphism. Schistosity and bedding are almost always parallel, and here as usual in the entire Selkirk series, the recrystallization of the original muds was accomplished under the static condition of deep burial, and before orogenic deformation.

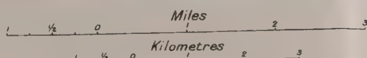
At Illecillewaet (102·8 mls.) the dip has flattened to 10°—15° N.E., with local crumpling. The dip increases to 25° and then to 40° N.E. at

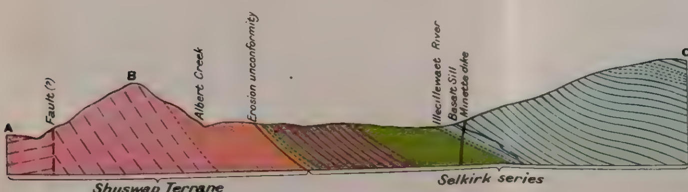

A
Fault (?)



Geological Survey, Canada

Albert Canyon





Section along line A-B-C

Miles and
Kilometres.

107· m.
172·2 km. **Illecillewaet Gorge** (Albert canyon)—Alt. ca. 2,450 ft. (747 m.). In the gorge an excellent view of the lower beds of the Laurie group is obtained. A thickness of about 200 metres is represented in continuous outcrop. A few thin lenses of blackish limestone and the basal 15-metre bed of light gray limestone (seen at the west end of the rock cut) are intercalated in the dominant metargillite. In the railway cut may be noted the only intrusive rocks known in our section between Glacier and Albert Canyon station. One of these is a narrow N-S. trending, nearly vertical dyke of minette, with small, completely altered, phenocrysts of augite. The other is a 1-metre sill of common, highly vesicular (!) basalt, which locally breaks across the bedding of the metargillite.

On the way to Albert Canyon station, a few rock-cuts in the Illecillewaet quartzite and Moose metargillite are passed. On the right the north branch of the Illecillewaet joins the main river.

109·4 m.
176·0 km. **Albert Canyon station**—Alt. 2,221 ft. (677 m.). A prolonged stop is made at this point for the double purpose of viewing the basal unconformity between the Selkirk series and the Shuswap terrane; and of becoming acquainted with an igneous phase of the latter series of rocks.

About 800 metres from the station, on the northwest bank of Albert (Moose) creek, the zone of unconformity has been laid bare for inspection. The high precipices visible on the east and north are composed of the dark-coloured strata of the Moose metargillite, Illecillewaet quartzite, and Laurie metargillite, dipping to the northeast. The Moose formation is largely hidden beneath the thick forest on the ridge due south but preserves its monoclinal attitude to the underlying limestone. This fine-grained marble is seen at the crossing of Albert creek, where

it passes, by interbedding, into the "basal quartzite." (See p. 133).

The unconformity is here not marked by a conglomerate but by a fine-grained feldspathic sandstone, very similar in appearance to the altered orthogneiss beneath. The basal quartzite is interpreted as a statically (and dynamically?) metamorphosed arkose sand derived from the adjacent orthogneiss and washed but a short average distance from the parent, pre-Beltian ledges. It is practically impossible to indicate the exact plane of the unconformity, but it may be approximately located at the horizon where aplitic dykes cutting the orthogneiss cease to be visible in the quartzitic rock. The uncertainty is partly due to the intense static metamorphism of older and younger rocks alike; partly, to the deep weathering of the orthogneiss before it was covered by the bedded arkose. Microscopic study shows that, for depths of 60 to 75 metres stratigraphically below the surface of unconformity, the orthogneiss has been thoroughly altered. This alteration is apparently only explicable as due to profound secular weathering preceding deep-burial metamorphism.

Opportunity will be afforded for a more extended study of the orthogneiss itself. It has the form and relations of a broad laccolith or sill, with a thickness of 1000 metres for the part still remaining after the Beltian erosion. Along the railway the mass can be well seen to show a persistent gneissic structure which is closely parallel to the bedding and fissility of the overlying Beltian strata. The lower contact of the sill crosses the railway at a point about 2000 metres west of Albert Canyon station. There the ancient granitic magma was clearly intruded along a plane parallel to the banding in dark schists probably in part of sedimentary origin. These bedded Shuswap rocks and the great intrusive sheet evidently lay nearly horizontal while the Beltian strata were being deposited upon them. Their flat position was typical

Orthogneiss near Albert Canyon station, schistosity due to static metamorphism.

Miles and Kilometres.

of the rocks of the Shuswap terrane until the revolution which flexed the Rocky Mountain Geosynclinal into the folds of the Selkirk range.

The thoroughness of the static metamorphism suffered by the orthogneiss is very striking. In part the completeness of the recrystallization of the granite may be explained by burial under the enormous mass of geosynclinal sediment, but it should be noted that similar metamorphism is shown in the Shuswap orthogneisses far to the west where the Beltian-Cambrian strata were, apparently, never deposited in great strength. It seems probable that the advanced static metamorphism of the older Shuswap rocks was already accomplished in pre-Beltian time.

At this section along the railway track, one can see samples of the many aplitic and pegmatitic dykes cutting the orthogneiss and schists beneath it. The abundance of these igneous intrusions here, together with their entire absence in the adjacent Beltian strata, is one of the leading proofs of an important erosion unconformity at the base of the Selkirk series.

From the 110th mile-post, near Albert Canyon, to Shuswap station, 116 miles (186·7 km.) farther west, the railway runs almost entirely over the Shuswap terrane. For the first 30 kilometres the line crosses a dominantly igneous phase of the formations composing this second principal province of the Canadian Cordillera. Biotitic and hornblendic orthogneisses are the chief rock types until the Columbia river at Revelstoke is reached. These metamorphosed granites are all pre-Beltian but show different dates of intrusion. The oldest masses observed are generally hornblendic and are sills cutting coarse sedimentary (?) mica schists; or are larger bodies (batholiths?) without clear indication of shape. The hornblendic granites seem to have been statically metamorphosed into gneisses at an early date, for the younger,

Map showing approximate distribution of the Shuswap terrane rocks in south central British Columbia.

Miles and Kilometres.

generally biotitic orthogneisses characteristically occur as sills following a pre-existent, flat-lying foliation in the older rocks. The abundant masses of the later group were themselves rendered gneissic by a similar type of metamorphism and then injected by myriads of thinner sills, dykes, and chonoliths of white or pink pegmatite and aplite. These youngest members of the complex are less affected by metamorphism, though a gneissic structure parallel to sill-contacts is often seen also in them.

The whole assemblage of rocks is in striking contrast to that in a normal batholithic province of a post-Cambrian date of intrusion, and one cannot but suspect that some of the conditions of rock formation in this typical "Archean" field were peculiar to an early epoch in the earth's history.

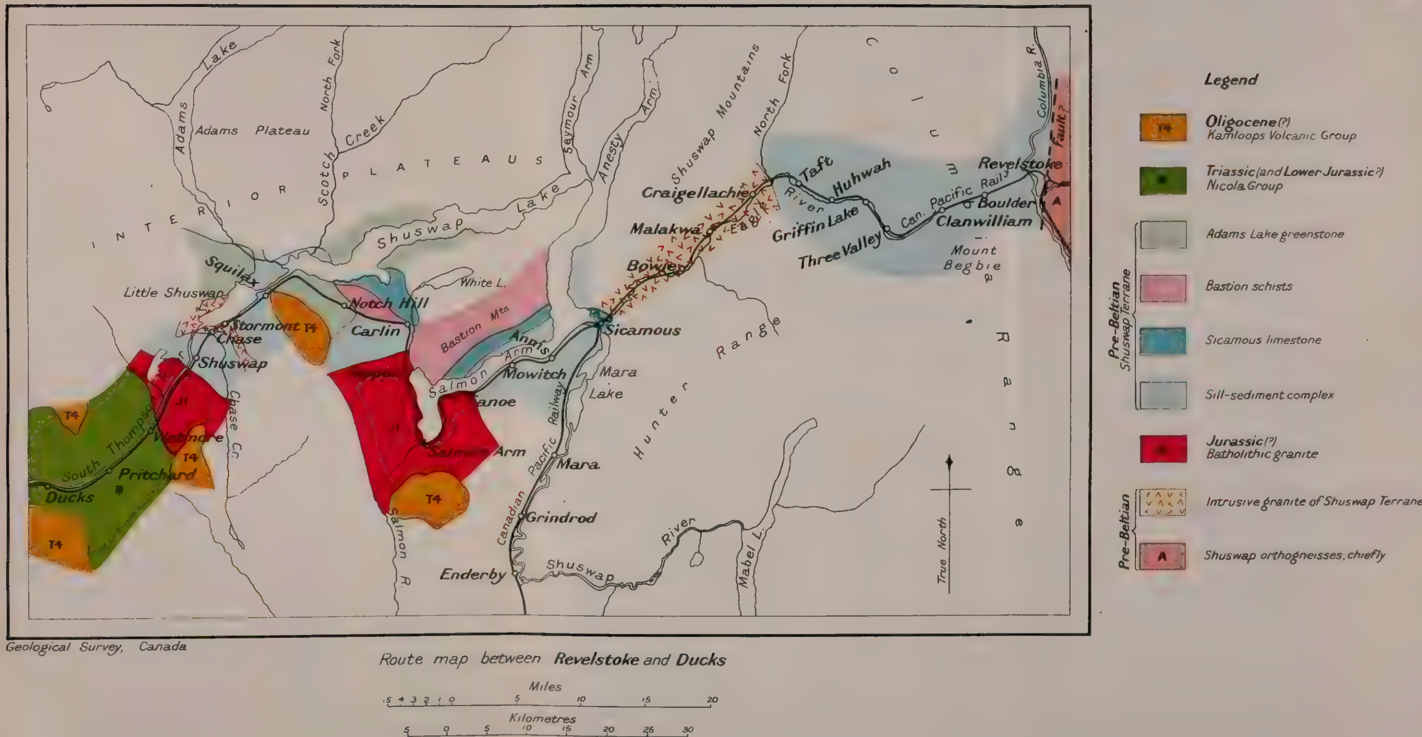
The gneissic complex is not well exposed in the Illecillewaet valley except in a few places where forest fires have bared the ledges. An example is seen on the left, for several kilometres between Twin Butte station and Greely siding (124·2 mls.; 199·5 km.).

119·6 m. 192 km. **Twin Butte Station**
Greely Siding

Near the 128th mile-post the river cascades over schists and gneisses on which it has been locally superimposed through its own alluvium. At this point is the power plant of Revelstoke. As the train turns sharply to the right, one sees the fore-set beds of the delta built by the Illecillewaet into the Columbia valley when it was here laked, with a water level about 70 metres above that of the present Columbia. It is probable that this water-body was a great expansion of the existing Arrow lakes.

130·3 m. 209·7 km. **Revelstoke**—Alt. 1,492 ft. (455 m.) an important distributing centre in the interior trade of southern British Columbia.

The orthogneisses, aplites, and pegmatites can be easily studied on the mountain slope rising directly from the railway yard.



Route map between **Revelstoke** and **Ducks**

Miles and Kilometres.

The town lies in the '*Selkirk Valley*,' namely, that part of the Columbia river valley which bounds the Selkirk mountain system on the west and separates it from the long Columbia system, which across the valley rises to heights approaching 9,000 feet (2,743 m.). This long depression has a complex history and is of composite origin, though the details of neither have been worked out. Over most of Revelstoke mountain, north of the town, the strikes average about N.N.W.—S.S.E., a Cordilleran direction corresponding probably to fault-blocking during one of the post-Cambrian periods of mountain-building. Across the river the strikes average nearly E.—W. At its eastern bank, 5 kilometres above Revelstoke, these structural lines are found in close proximity, indicating a N.—S. fault on which the river is located. Other local evidence agrees with the view that this part of the Selkirk valley has been formed by erosion on a longitudinal fault of unknown but possibly considerable throw. The downthrow is probably on its eastern side.

Along the branch railway to Arrowhead, 44 kilometres southward from Revelstoke, one may observe the prevailing low dips in the Shuswap terrane.

From Revelstoke to Kamloops the mile-posts are numbered in a new series, beginning in the east, and distances are stated accordingly.

At the crossing of the river one notes its increase of size, accomplished in its 300-kilometre journey from Beavermouth where it was last seen. In that distance the river has rounded the northern end of the Selkirk range, and it is here flowing south toward the lava fields of Washington State. After running over one of the terraces characteristic of this valley, the train reaches some extensive artificial cuts in the *Tonkawatla paragneiss*. (See page 123.)

The normal orthogneisses, developed as thick sills and many dykes cutting the sediments and problematic basic schists, begin to appear as the low divide of the Columbia range is approached, near Clanwilliam.

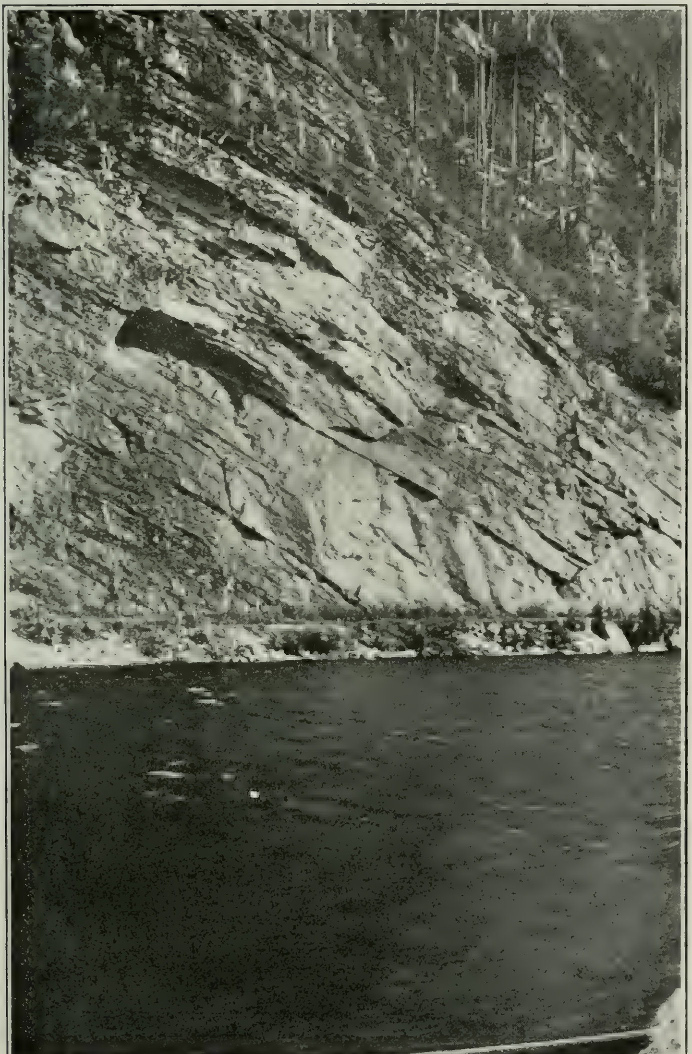
Miles and Kilometres.

8·9 m. 14·2 km. from Revelstoke. **Clanwilliam station.**—Alt. 1,812 ft. (552 m.). The rock-cuts here afford excellent exposures of a dominantly sedimentary phase of the Shuswap terrane. Paragneisses, mica schists, quartzites, and subordinate limestones (cut by granite sills) are flexed into an anticlinal fold pitching to the west. Tonkawatla creek and the deep col at the divide are located in the heart of this fold. The stratigraphic place of the sediments in the Shuswap series is not clear. The older beds are much like the Tonkawatla formation, and the quartzites have striking resemblance to the Chase formation exposed near Shuswap village. The still younger mica schists overlying the quartzite may represent the Salmon Arm formation. (See p. 124.)

At the western end of Victor lake, 2 kilometres west of Clanwilliam, a 200-metre sill of biotite granite has been thoroughly sheared and its femic constituents, especially the mica, have been segregated in thick, black bands. This strikingly banded orthogneiss is a result of *dynamic* metamorphism which is comparatively seldom exhibited in the Shuswap terrane.

14·7 m. 24·8 km. From **Three Valley station** to Sicamous (45·1 mls.) the line runs through a field of orthogneisses cutting rarely exposed, rusty mica schists, probably of sedimentary origin. Strong jointing and the fissility of the schists are conditions which have led to extensive land-slides, visible at and for some kilometres beyond Three Valley.

21·1 m. 33·8 km **Mitikan Siding**—Alt. 1,300 ft. (396 m.). To the south may here be seen a high bluff seamed with many pegmatitic and aplitic sills. From a more commanding position their number in this slope has been estimated to exceed two hundred; their thicknesses range from 1 metre to about 200 metres. They cut rusty crystalline schists which are in part sedimentary, enclosing occasional thin beds of limestone.



Quartzites, mica schists and paragneisses, showing coincidence of bedding and schistosity; Shuswap series. At Summit lake, Columbia range, in railway section.

Miles and Kilometres.

From Taft station (24·5 mls.) nearly to Sicamous the line runs over massive orthogneiss generally rich in hornblende and thus contrasted with the dominant biotitic gneisses of the Shuswap terrane. Near Taft the hornblende gneiss is in sill relation to the rusty (metasedimentary?) schists, but beyond Craigellachie (28·5 mls.) it seems to have the continuous character of a batholith or extremely thick laccolith.

Approaching Sicamous, the train crosses the delta of the Eagle river which has grown so far as to nearly isolate Mara Arm from the main Shuswap lake.

45·1 m. 72·6 km. **Sicamous**—Alt. 1,147 ft. (350 m.). The Shuswap lakes have a total length of about 150 kilometres. They represent profound changes in the drainage system under the influence of Pleistocene glaciation. Not only were water-divides and stream directions modified at that time; the graded valley-floors were converted by Glacial erosion into series of rock basins. Drift barriers have also co-operated in the formation of these fiord-like lakes. The greatest depth recorded for the Shuswap lakes is 447 feet (136 m.), measured about 11 kilometres north of Sicamous. The neighbouring Adams lake, 70 kilometres long and 1,200 feet (366 m.) deep, is a pure type of rock basin. Part of its floor is almost at sea-level.

From Sicamous the excursionists will obtain their first view of the Belt of Interior Plateaus here merging into the more rugged Columbia range just traversed. The origin of the upland facets of these plateaus is a problem not yet completely solved. As a whole, however, they represent a late Miocene or early Pliocene land surface, dissected by streams revived because of the general Cordilleran upwarp during the Pliocene period. (See pp. 162-164.)

At and west of Sicamous station a partial section of the Sicamous limestone (p. 124) may be studied. It occurs in a fault-block showing the exceptional Cordilleran N.W.—S E. strike,

View in belt of Interior Plateaus looking westerly down Shaswap lake near Blind bay.

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with northeasterly dip. As one goes westward he descends in the series and finds the limestone becoming increasingly charged with sills of orthogneiss and aplite. Near the 47th mile-post the limestone is apparently underlain by a massive quartzite interrupted by films and thin beds of coarse muscovite schist. This may represent a siliceous member of the Salmon Arm formation or else the younger Chase quartzite. The coarseness of the mica schist and the massiveness of the lowest beds of limestone are explained by the thermal metamorphism exerted by the abundant sills. In the southeastern slope of Bastion mountain across the lake, the coarse, glittering (Salmon Arm) mica schists cut by many granitic sills pass up gradually into a fine-grained metargillite almost free from intrusives, and the latter rock is conformably overlain by the normal, fissile Sicamous limestone.

One of the best exposed sections of the Shuswap series is that exhibited as a great monocline from Canoe point, along the western shore of the lake, to Cinnemousun narrows, 23 kilometres distant. Green schist and massive limestones, corresponding to the youngest recognized members of the Shuswap series, are found near the narrows and at the top of this northerly-dipping monocline. The rocks on the opposite shore of the lake, north of Sicamous, are largely orthogneisses and have attitudes usually quite different from those of the monoclinal section. The valley of this part of the main lake therefore seems to be located on a fault with downthrow on the west.

From the limestone band just west of Sicamous to the 56th mile-post the line crosses the Salmon Arm schists injected with many sills and dykes of orthogneiss, pegmatite and aplite.

At 56·2 miles (90·4 km.) a large rock-cutting shows a coarse porphyritic syenite, which crops out again at the southwestern base of Bastion mountain nearly due west, across the lake. This rock appears to be a peripheral phase of

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a batholith extending southward and westward for many kilometres and northward a short
71 m. distance beyond **Tappen station.** The central
114·2 km. and greater part of the batholithic mass is composed of biotite granite. Like the syenitic phase, it is massive, relatively little crushed, and lacking the multitude of pegmatitic injections so characteristic of the Shuswap orthogneisses. This batholith thus seems to be of post-Shuswap date and it is tentatively referred to the late Jurassic period of granitic intrusion.

The bold bluff of Bastion mountain north of the Arm is composed of the Sicamous limestone dipping 28° to the N.W. The limestone forms a continuous band along the southern face of the mountain to the shore of the main lake north of Canoe point, and 15 kilometres from the bluff overlooking Tappen.

Looking southward from Salmon Arm, a thick cap of Tertiary lava (basalt and augite andesite of the Kamloops groups), unconformably overlying the granite, is seen in Mt. Ida. This is the first of many similar remnants of these Oligocene (?) volcanics to be encountered in the railway belt. (See page 148.)

As the train leaves Tappen and climbs the grade to Notch Hill station, the dark Bastion schists overlying the Sicamous limestone may be observed occasionally across the valley.

80·1 m. **Notch Hill Station**—Alt. 1,685 ft. (513 m.).
128·9 km. At this point the line is crossing greenstones and chloritic schists, representing the volcanic Adams Lake member of the Shuswap series (page 124) or else much metamorphosed 'ntrusives of the same general epoch. The Blind Bay valley is floored with the Sicamous limestone presumably repeated here by a strike-fault. The ridge southwest of Notch Hill is composed of a second outlier of the Oligocene(?)
87·8 m. lava-field. Near **Squilax station** the railway
144·5 km. touches the unconformity between this volcanic cap and the Shuswap green schist formation. Here the growing delta of Adams river draining

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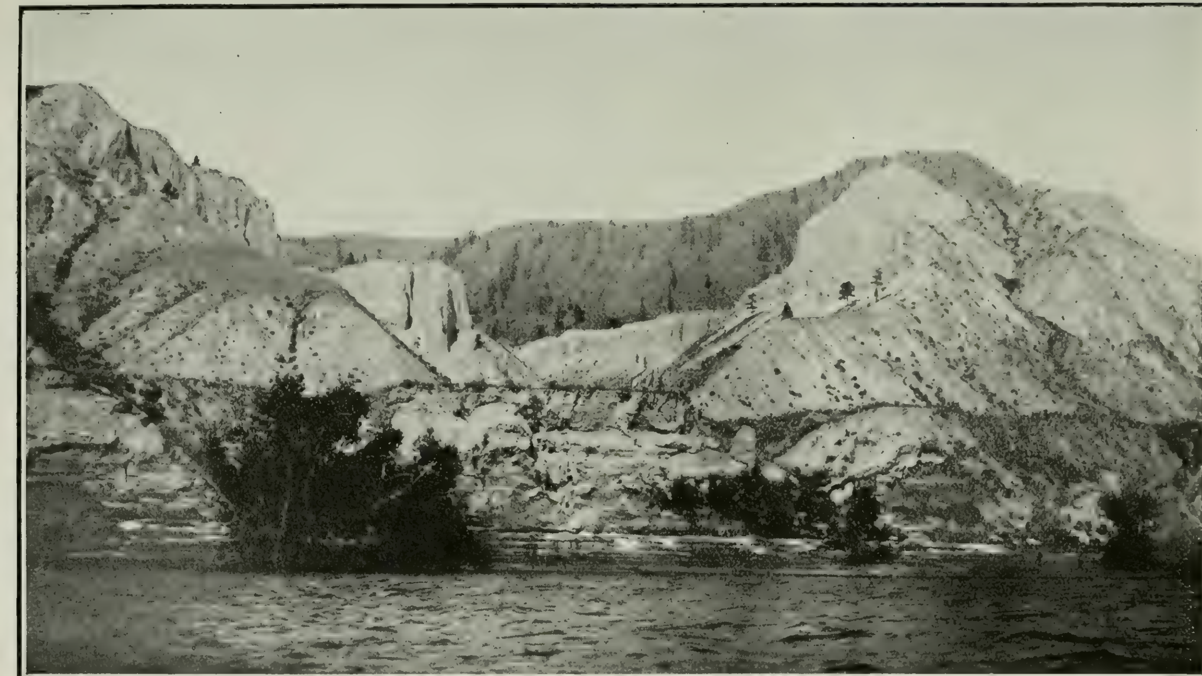
the long Adams lake can be seen to separate the main Shuswap lake from Little Shuswap lake.

The smaller lake basin has been eroded in Shuswap orthogneiss with the form and relations of a large irregular laccolith cutting the Chase quartzite and coarse mica schists of the same habit as that characterizing the Salmon Arm schists thermally metamorphosed. The laccolith is itself gneissic. Its planes of schistosity, like its contacts and the invaded sediments, dip 55–60° to the N.N.W. The E.N.E. end of the body is near Squilax; the W.S.W. end appears on the ridge across the river from Shuswap station. Where observed, the upper contact of the laccolith is made with the Salmon Arm(?) schists or with (intrusive?) greenstone of Shuswap age. The schists below the lower main contact are heavily injected with ortho-
91·9 m. gneiss sills, and at **Stormont siding** the massive
147·9 km. orthogneiss cross-cuts the sediments as a very broad dyke extending southeastwardly through the mountain. This 'dyke' may represent the main feeder of the laccolith.

Between Chase (94·0 m.—151·3 km.) and Shuswap station (95·9 m.—154·3 km.), the line nearly parallels the strike of the coarse Salmon Arm schists. The cliffs east of Shuswap are composed of the underlying, massive Chase quartzite dipping 50° to the N.N.W. (See page 123).

A short distance beyond this station the sediments are truncated by a homogeneous granite, little strained and with other characteristics of the post-Paleozoic (late Jurassic) batholiths. With its abrupt appearance the section leaves the Shuswap terrane.

Terraces become more and more prominent features in the valley floor. Their material is remarkably fine-textured, homogenous silt, showing distinct, even, bedding. As Dawson recognized long ago, it is clearly a lacustrine deposit and dates from the late Pleistocene. Since the silt was not deposited in the basin of Little Shuswap lake, it is most probable that that



Silt terraces on South Thompson river, with Pennsylvanian formations (Cache Creek series) in the back ground. Looking north from a point about three miles above Kamloops.

Miles and Kilometres.

basin was closed by a thick valley glacier at the time of silt deposition. The valley was similarly dammed by a large, local glacier entering from the valley of the North Thompson. Throughout the distance from Shuswap nearly to Kamloops—50 kilometres—the valley of the South Thompson was thus laked, and fine, white silt was accumulated to depths greater than 120 metres.

Nine kilometres beyond Shuswap station, the western contact of the granite is reached. It is here intrusive into the rocks of the Nicola series, in which the valley of the South Thompson river is sunk for a distance of 19 kilometres (102 mls. to 118 mls.)

The first rocks of this series to be crossed constitute a thick well-stratified body of hard sandstones and fine-grained strata shown to be in part bedded volcanic ash, but probably in part true argillites. Subordinate volcanic breccias of basic composition are interbedded. The whole forms the youngest local phase of the Nicola series conformably overlying the massive lavas of the Triassic, and is itself either upper Triassic or Jurassic in age. The dips here range from 60° to 80° to the east, indicating an apparent thickness of more than 2,000 metres for this stratified member.

104 m.
168.6 km. Just beyond **Pritchard siding** is its (lower) contact with the very massive lavas of the Triassic Nicola series (see p. 145). These can be well seen in dark coloured bluffs across the river. Their structure is extremely difficult to decipher. Pyroclastic beds are rare; thick flows (and sills?) of basaltic lava are dominant. Wherever the dips can be observed they are steep, generally 50° to 90°, with strikes ranging from N.-S. to N.W.-S.E.

To right and left the distant summits are capped by Tertiary basaltic lavas (Kamloops group) with associated fresh-water sandstones. These have low dips and overlie the more massive, more deformed, and more altered Triassic volcanics unconformably.

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Kilometres.

111·9 m. 180·1 km. **Ducks station**—Alt. 1,146 ft. (349 m.). At this point the Nicola rocks are specially well seen, across the river. Three kilometres to the south-east, the Tertiary lavas are now dipping at angles varying from 45° to 90°, indicating the local vigour of the last orogenic deformation (late Miocene) in British Columbia.

At and beyond Ducks station, the silt terraces are very conspicuous.

At the 118th mile-post, nine kilometres beyond Ducks, the Triassic series can be seen north of the river, resting on the Carboniferous (Pennsylvanian) limestone, the light gray colour of the latter contrasting well with the deep tint of the Nicola lavas. The relation is that of unconformity, since the lavas are underlain by a basal conglomerate containing chert pebbles derived from the limestone. The conglomerate and the plane of unconformity dip east at an average angle of about 50°, The limestone has a variable attitude but also dips at a high angle to the eastward. The agreement seems to show that the pre-Triassic deformation of the Carboniferous strata was not severe.

This is one of the best exposed contacts between these two great series yet found in British Columbia.

Continuing to Kamloops, the route crosses the Carboniferous rocks. (See p. 144). The dark-coloured ledges are chiefly composed of cherty quartzites and altered argillites, but some basic volcanic ash and coarser pyroclastic material is also interbedded. At intervals, light gray vertical bands represent as many occurrences of older fossiliferous Pennsylvanian limestone. The general structure north of the river, through to the North Thompson river, is the monoclinal. The strike averages N. 35-40° W.; the dip, 75-80° to the N.E. Yet there are a few local reversals of the always steep dip, and it is likely that the total thickness calculated from

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the generalized monocline is deceptively great. Nevertheless, a minimum thickness of 2500 metres of Pennsylvanian beds seems to be represented. It is improbable that pre-Pennsylvanian formations occur in this section.

122·1 m.
207·8 km.

Kamloops—Alt. 1,151 ft. (351 m.)—is another important distributing centre for the interior trade of the province. Its location was determined by the confluence of the South Thompson and North Thompson valleys; the one followed by the existing Canadian Pacific Railway, the other now witnessing the completion of a second transcontinental line (Canadian Northern Railway). Since leaving Little Shuswap lake the country has become rapidly drier and Kamloops is the centre of a scattered farming and grazing community largely dependent on irrigation facilities.

Beyond Kamloops the mile-posts begin a new sequence of numbers; distances will be stated accordingly.

Just outside the western limit of the town the railway crosses a band of massive traps referable to the Nicola series. These are unconformably overlain by low-dipping Tertiary (Oligocene?) lava flows and tuffs, containing the fossiliferous Tranquille sandstones and shales (see p. 149). These can be seen on both sides of the river delta now growing rapidly into Kamloops lake through the activity of the silt-laden river. The Tertiary sediments may be seen, on the left, at **Tranquille Siding.**

8·0 m.
12·8 km.

Just beyond that point the line skirts the long cliff called "Cherry Bluff." The massive rock composing it is a sheared and greatly altered mass of variable, dioritic to monzonitic and even gabbroid nature. The body is 8 kilometres long and 4·5 kilometres in maximum width. The lake lies in its major axis and the replica of Cherry Bluff is to be seen in "Battle Bluff" across the water. The granular rock is clearly intrusive into the Nicola traps, which form part of its roof both north and south of the lake. The relation to the Tertiary series is

Miles and Kilometres.

not so obvious. The Oligocene (?) lavas and sediments dip away from the intrusive on all sides, as if the intrusive were a partially unroofed laccolith of later Tertiary date of intrusion. One difficulty standing in the way of full belief in this hypothesis is the advanced shearing and alteration of the intrusive; a similar condition is extremely rare in the post-Oligocene intrusives of the Cordillera. According to a second interpretation the laccolith dates from the Triassic, representing a late phase in the eruptivity of that period. On this view the shearing of the intrusive and the deformation of the Tertiary rocks would be explained by a post-Oligocene, orogenic doming of the whole complex of solid rocks.

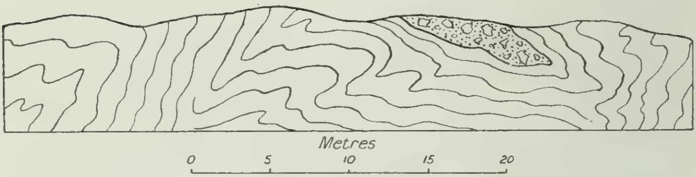
14·6 m. 23·4 km. **Cherry Creek station.**—Alt. 1,134 ft. (346 m.). Here the southeastern contact of the great intrusive is crossed and the line then runs continuously over the Triassic (Nicola) traps (with fossiliferous interbeds of limestone) to Savona (25·3 m.—40·7 km.).

19·7 m. 32 km. At **Munro Siding** the "Painted Bluffs," east of Copper creek across the lake, are in full view. These are composed of brilliantly coloured Tertiary volcanic rocks. The Tranquille tuff beds which underlie the basaltic lavas of the Kamloops group, vary from pale buff or dull green to dark red, brown or gray in colour, and are largely altered. Plant and fish remains are found in these beds which place them provisionally in the Oligocene. The sequence of the lavas and pyroclastics on the north side of the lake is almost identical with that exposed on Savona mountain on the south side. It is thought that the sections are on the limbs of a broad anticlinal dome since bevelled off during a Pliocene erosion cycle. The surface resulting is well preserved on both Hardy and Savona mountains.

West of Copper creek, on the hillside may be seen the sites of cinnabar mines which have produced 7,000 lbs. (3,175 kg.) of mercury. The cinnabar is associated with small quantities of stibnite and has a calcite-quartz gangue.

The ore is found in irregular veins traversing an altered, now dolomitic greenstone containing pyroxene and olivine.

The silts forming occasional benches on the shores of Kamloops lake are often seen to have been crumpled by overriding ice which occupied the valley during a temporary increase of glacial activity in the late Pleistocene.



Section illustrating great crumpling of Glacial silts by advancing ice sheet which deposited typical till on the silts. Locality 3.5 km. west of Cherry Creek station.

WESTERN PART OF THE BELT OF INTERIOR PLATEAUS.

(SAVONA TO LYTTON.)

BY

CHARLES W. DRYSDALE.

ESSENTIAL GEOLOGY.

INTRODUCTION.

That portion of the British Columbia Cordillera which lies between the Columbia Mountain system on the east and the Coast range on the west, is known as the Belt of Interior Plateaus. It is with the section between Kamloops lake and Lytton, along the course of the Thompson river which traverses this belt, that the following outline of geology deals.

The district was first examined geologically in 1877 by G. M. Dawson [**1**] and again by him in a more detailed

manner during the summers of 1888, 1889, 1890. The results of his work are contained in the Report on the Kamloops Map Sheet [4].

Physiography.

As viewed from the wide, open valley of Thompson river, the Kamloops district presents a hilly and even mountainous relief, the bordering summits rising from 4,000 to 5,000 feet (1,200 to 1,500 m.) above the level of the river. A broad summit view, however, explains why it is included among the Interior Plateaus of British Columbia, fcr from about the 4,000-foot (1,200 m.) level, there stretches as far as the eye can see a series of gently undulating and plateau-like upland surfaces. Within the upland, the younger valleys appear to be deeply entrenched.

Both the annual and daily range of temperature is great. On account of the very slight rainfall, the region is commonly known as the "Dry Belt of British Columbia."

Where irrigated, the semi-arid land of the valleys, commonly covered with sage brush, cactus, scattered yellow pine, and thickets of poplar, is very productive of fruits and vegetables. The grassy "park country" of the upland affords good grazing for cattle, and a supply of timber for the ranches.

For the explanation of relief in the district at least three cycles of erosion must be considered: one in Cretaceous; one in pre-Miocene; and the latest in Pliocene time. It is to the Pliocene erosion cycle that the present upland topography chiefly owes its development.

The facts upon which the above tentative conclusions are based are as follows:—

1. Early Tertiary (Eocene ?) conglomerates rest directly upon the upper Jurassic batholith south of Walhachin. The conglomerate is largely composed of well water-worn boulders of granite and Paleozoic metamorphics. As granite batholiths consolidate under considerable thicknesses of superincumbent material, such conditions would necessitate the removal by erosion of the entire cover from the batholith. A great thickness of rock must, then, have been removed during the Cretaceous period.

2. The absence of Upper Cretaceous rocks in the district, and the entire absence of Cretaceous rocks east of

Ashcroft would imply continental conditions and consequent erosion during at least late Cretaceous time.

3. South of Kamloops lake at an elevation of about 2,000 feet (610 m.) an extensive flat is underlain by Jura-Triassic rocks, and entrenched by an early Tertiary river valley. The old river valley is filled with Coldwater conglomerate, sandstone, and shale dipping at low angles. The rocks of this formation form prominent strike ridges which rise high above the flat referred to, and form, at the contact, a topographic unconformity. The flat is a conspicuous topographic feature, and is thought to represent a remnant of an old uplifted Cretaceous erosion surface since modified by Glacial action. Here, through favourable tectonic conditions, a portion of the Cretaceous erosion surface has been preserved to the present time and dominates the topography.

4. The next erosion cycle provisionally referred to pre-Miocene and post-Eocene time, is evidenced by a marked unconformity between early Tertiary formations and lower Miocene (?) volcanics. Near Ashcroft, as elsewhere throughout the Belt of Interior Plateaus, the early Tertiary formations are strongly uptilted, and they have been apparently subjected to crustal disturbances prior to the later vulcanism. Such orogenic movement would naturally inaugurate a new cycle of erosion which probably removed vast quantities of the loose continental deposits of early Tertiary age.

5. The third and most important erosion cycle which is thought to have largely developed the present upland topography, continued into the Pliocene.

The Miocene (or Oligocene?) lavas which cap the hills in so many widely scattered localities throughout the Belt of Interior Plateaus, have been warped to form broad synclinal basins and anticlinal domes. The anticlinal domes have since been removed through denuding agencies. It is found that the present late mature upland (locally a peneplain) truncates or bevels the tilted lavas for great distances. The upland erosion surface in this district may be correlated with one found by the writer during the summer of 1911 in the Franklin Mining district in the Columbia Mountain system. There it truncates the Midway Volcanic group of trachytes and alkalic basalts referred to the Miocene period.

GLACIATION.

The deep pre-Glacial Thompson valley contains a great thickness of fluvio-glacial material now in process of being excavated. Sections of such glacial and interglacial debris exposed by the river and railroad, aid considerably in the determination of the Pleistocene history of the province.

The region of Interior Plateaus was, during the Pleistocene, covered by the Cordilleran ice cap, whose direction of flow here, as shown by striæ, was about S. 35° E. The upland slopes are thickly mantled with morainic drift and erratics left stranded by the retreating ice sheet. On the other hand, the contemporaneous boulder clay deposited in the valleys below, has since been largely removed by the advance of valley glaciers.

With its waning, the Cordilleran continental glacier gave place to alpine, cirque, and valley glaciers. Much englacial and superglacial material was deposited and reworked by water. The older gravels, sands, and stratified clay silts, capped by boulder clay, are referable to this period of alluviation, contemporaneous with the first period of valley glaciation.

The valley ice slowly retreated until the time of the maximum extension of the Keewatin ice sheet on the east, when the second period of valley glaciation in the Cordilleran belt probably took place. This advance of the ice removed much of the older morainic and outwash materials, deeply eroded the valleys, and heaped up lateral and terminal moraines. The high-level esker-like ridges of the valley sides probably represent the work of streams at the borders of the ice. The streams draining the ice front carried down and deposited large quantities of land waste in the form of a deep alluvial fill.

With the melting and recession following the maximum advance of the second period of valley glaciation, large amounts of drift materials were set free. Great thicknesses of silts were then deposited in the tranquil waters of lakes. These lakes were formed on the main valley floors, either dammed by powerful local glaciers entering from the sides, or perhaps locally basined at a time of special subsidence yet greater than that recorded for the late Pleistocene along the Pacific shore. At the mouths of tributary creeks alluvial fans composed of cross-bedded gravels

and sands, were laid down under water and are intercalated in the White Silt formation.

Following the complete withdrawal of the ice from this portion of the Cordillera, the denuded region of former vigorous glaciation would supply but little rock waste to the streams. With the reduction in waste supply and but a moderate reduction in volume, the streams here deeply degraded the earlier accumulations. Degradation was probably further aided by regional uplift which invigorated the streams. Terraces due to the normal lateral swinging of the river, as well as to later minor stages of alluviation and degradation dependent upon climatic change, are present throughout the Thompson valley. An old river bed is found to lie persistently in sharp contact with the White Silt for many miles. It is represented by a coarse gravel with boulders overlapping each other in the direction of flow. It is generally found directly beneath the surface silt and sand of the terrace on the bed-rock side of the valley.

The district between the east end of Kamloops lake and Lytton may be divided into three distinct sections. The eastern section covers Kamloops lake, where the Thompson valley appears to have been glacially deepened to a great extent The result is that the tributary valleys bear hanging relationships to the main valley. There are well developed alluvial fans and cones chiefly of subaqueous origin, at the mouths of the tributary creeks. The main valley itself is comparatively free from glacial outwash material.

The central section extends from the west end of Kamloops lake (26 miles—42 km.) to Thompson Siding (85·3 miles—158k m.). It is characterized by a great depth of Glacial valley-train material, beautifully terraced by the meandering Thompson river. The deeply incised river, however, has only in a few places reached the rock floor of the old pre-Glacial valley.

The western portion of the central section from Toketic to Thompson Siding, owing both to the increased gradient of the river and the narrowness of the valley, contains only narrow terrace lands, and a comparatively small development of the White Silt formation.

The western section, from Thompson Siding to Lytton (9·48 miles—153 km.)—the Thompson Canyon proper—, displays a very mountainous appearance in bold contrast

to the eastern belt. Here the Thompson river has cut completely through the outwash valley-train and has deeply incised itself within the pre-Glacial floor of bed-rock, forming a deep canyon. The canyon bottom contains many huge blocks of rock that have tumbled from above, and are now in process of being broken up and carried downstream by the turbulent river.

STRATIGRAPHY.

The bed-rock geology has chiefly to do with formations of Mesozoic and Tertiary age.

The following is a table of formations in descending order:—

	Approximate thickness (after Dawson).		
Pleistocene and Recent.			Superficial deposits. Glacial till, gravel, sand, clay and silt.
	Feet.	Metres.	
Lower Miocene (?) *	3,000	914	Kamloops Volcanic group; basalt, agglomerate, breccia, trachyte.
	1,000	305	Tranquille beds; fine-grained tuffs.
Eocene (?).......	5,000	1,524	Coldwater group; conglomerate, sandstone, Ashcroft rhyolite porphyry.
Lower Cretaceous.	5,000	1,524	Queen Charlotte Islands formation (?); shales, conglomerate and sandstone.
Jura-Cretaceous..	5,000	1,524	Spence's Bridge Volcanic group; andesitic and liparitic lavas, tuffs, and arkoses.
Upper Jurassic....................			Granitic intrusives; batholiths, stocks, and tongues.
Jurassic-Triassic..	10,000	3,048	Nicola formation; greenstone, impure quartzite, argillite, limestone, agglomerate and tuff.
Carboniferous....	9,500	2,896	Câche Creek formation; cherty quartzite, greenstone and marble.

* Dr. R. A. Daly refers these rocks tentatively to the Oligocene system. See page 149.

The *Câche Creek formation* consists of very badly metamorphosed sedimentary and eruptive material belonging to the Main Pacific geosynclinal. The commonest rock member is a cherty quartzite traversed by veinlets of quartz. Dark massive argillites and contemporaneous eruptives are of more local occurrence. Younger than the above rocks, but in many places intimately interfolded with them, is a limestone formation (*Marble Canyon limestone*) now recrystallized to marble. Large foraminifers known as *Loftusia columbiana* and the diagnostic Carboniferous fossil *Fusulina* are found in the Marble Canyon limestone. Much of the gold found in the placer workings along the Thompson and Fraser rivers may have been derived from the Cache Creek quartz veins. On account of the unfavourable character of the outcrops in the railway section it has here proved impossible to ascertain the full thickness. The estimate of Dawson is noted in the foregoing table.

The *Nicola formation* is well exposed in the Thompson valley and consists of greenstones (altered eruptives of both flow and fragmental type) intercalated with beds of argillite and limestone. Crinoid remains, pelecypods, terebratulas and pectens of several species are found in the calcareous members of the formation. These fossils place the series in the Triassic, grading up into the lower Jurassic. G. M. Dawson estimated that the thickness of the Nicola formation ranges from 10,000 to 15,000 feet. The agglomerates and porphyrites of this formation, by their much more metamorphosed and massive character, are readily distinguished from those of the Tertiary.

The batholiths, stocks and tongues which occur in the district are referred to the upper Jurassic. They are made up of granular intrusive rocks varying from granite to granodiorite and diorite, and are all subalkalic in composition.

During the Lower Cretaceous or late Jurassic, volcanic eruptions broke forth along the east front of the Coast range resulting in the accumulation of over 5,000 feet (1500 m.) of acidic and intermediate lavas and tuffs—the *Spence's Bridge Volcanic group*. This group has heretofore been referred to the Miocene (Lower Volcanic group of Dawson) but recently discovered plant, structural and physiographic evidence place the group in the Lower Cretaceous or late Jurassic.

Like the Coldwater group, the rocks of the Spence's Bridge Volcanic group have been much broken and metamorphosed prior to the outpouring of the Mid-Tertiary lavas.

In the vicinity of Ashcroft, carbonaceous shales, sandstones, and conglomerates occupy a local synclinorium striking nearly north and south. The western portion of the inlier is more steeply inclined and folded than the eastern, where the rocks appear to overlap flatly the Jura-Trias formation. This formation has been referred on lithological grounds to the Lower Cretaceous, and correlated with the *Queen Charlotte Islands formation* on the Pacific Coast.

Another inlier of Lower Cretaceous rocks occurs near the mouth of Botanie creek about two miles (3·2 km.) above Lytton. There, however, the dark shales, grey sandstones and conglomerates are much disturbed and slickensided.

The (probably Eocene) *Coldwater group* consists of continental sediments which include coarse fluviatile conglomerates, sandstones, and shale, with occasional coal. The deposits occupy erosion troughs cut into an older Cretaceous erosion surface. They have been locally upturned and eroded before the eruption of the younger Tertiary volcanics.

The *Kamloops Volcanic* group consists of basalts (both amygdaloidal and vesicular types), agglomerates and breccias, with smaller quantities of younger mica trachytes and various porphyrites. In the railway section the formation has an average thickness of about 2,500 feet (760 m.).

These lavas have a wide distribution through the Belt of Interior Plateaus, and as a rule lie almost horizontal. In places, however, they have been broadly folded into synclinal basins and anticlinal domes. The latter have been eroded away leaving the synclines at present exposed chiefly on the hill tops. Quite locally, but not within the limits of this section, these lavas have been tilted to vertical or nearly vertical positions.

Near the base of the Kamloops volcanics, a considerable thickness of evenly bedded tuffs occur—the *Tranquille beds* of G. M. Dawson. They are, as a rule, pale in colour and contain plant remains, thin coal seams, and occasionally fossil fish of lower Miocene or Oligocene age.

Deposits of Pleistocene age are very plentiful, and consist of Glacial till, gravels, sands, clays and silts.

SUMMARY HISTORY.

There is no record in the Kamloops district of pre-Carboniferous formations, and the area was probably subject to erosion during the early Paleozoic. The Main Pacific Geosyncline was initiated probably in Carboniferous time, and the Câche Creek formations laid down in an eastwardly transgressing sea. Sedimentation was interrupted at times by vulcanism.

The close of the Paleozoic was marked by deformation and a return to continental conditions. Submergence in Triassic time brought a return of marine conditions, with the deposition of argillaceous and siliceous muds and limestones, accompanied by volcanic activity on a grand scale. Vulcanism ceased in Lower Jurassic time and sedimentation continued with the deposition of arenaceous limestones rich in marine fauna.

Orogenic movements in the upper Jurassic were either preceded or followed by intrusions of granitic batholiths, stocks and tongues as well as volcanic activity along the east front of the Coast range (Spence's Bridge Volcanic group).

During the Lower Cretaceous marine conditions were locally restored in geosynclinal downwarps, which received the detritus washed in from the lands, especially from that on the east. Later an emergence took place and these areas seem to have shared in the erosion of the later Cretaceous. Therewith much of the cover of the Coast Range batholith was removed and the Interior Plateau country was brought down nearly to base level.

During the Laramide revolution the thick Mesozoic and older formatioms were greatly uplifted, locally folded and overthrust from west to east. The Coast Range and Columbia Mountain systems were loci of maximum uplift, and may have supported local alpine glaciers.

The Laramide revolution invigorated the drainage and made the rivers deeply entrench themselves within the older Cretaceous erosion surface. The Coldwater group conglomerates, sandstones and shales were then deposited in the erosion troughs and basins.

Local volcanic vents supplied rhyolitic lavas and acidic tuffs which are frequently associated with the early Tertiary formations. During the Oligocene which continued the erosive work of the Eocene, crusta

disturbances took place, uplifting and deforming the early Tertiary formations. This orogenic movement brought about vigorous erosion, and a great volume of the early Tertiary rocks was swept away. Volcanic activity broke forth on a grand scale in the early Miocene,* and great thicknesses of basaltic lavas, agglomerates, breccias and tuffs (Kamloops volcanics) spread over large areas. Crustal warping took place probably in the late Miocene and threw the flat-lying Kamloops volcanics in places into broad anticlinal domes and synclinal basins. Continued erosion in the Pliocene brought the whole belt to a stage of late maturity and local peneplanation. Wide and shallow, trough-like valleys were formed. At the close of the Pliocene or beginning of the Pleistocene, regional uplift took place, and the major streams deeply incised themselves within the uplifted erosion surface. During the Pleistocene, the Cordilleran ice-sheet advanced and retreated, leaving much drift. At least two distinct periods of valley glaciation and alluviation followed the retreat of the ice cap. The disappearance of glacier ice from the valleys increased the eroding activity of the streams which began the dissection of the alluvial gravels, sands and silts. This process of dissection, still active, was probably further aided by regional uplift.

* Dr. R. A. Daly prefers to give weight to the available paleontological evidence which tends to assign the Kamloops and Tranquille formations to the Oligocene. The time of their warping is accordingly to be described as the interval between the late Oligocene and the Pliocene period; and their extensive denudation is ascribed to work performed through practically all of post-Oligocene time.

ANNOTATED GUIDE.

(Savona to Lytton.)

Miles and Kilometres.

25·3 m. 40·7 km. (from Kamloops)

Savona—Altitude 1,158 ft. (352·9 m.). On Savona mountain which may be seen to the south of the town, occurs a thick section of the Kamloops volcanic group. In descending order it is approximately as follows:—

Coarse agglomerate on summit	200 ft.	60·9 m.
Reddish, black and greenish black lavas chiefly vesicular and amygdaloidal	900 ft.	274·3 m.
Agglomerates, varying to ropy lavas	800 ft.	243·8 m.
Grey, black, and red lavas, some vesicular, in places slightly agglomeratic	600 ft.	182·8 m.
Total	2,500 ft.	761·8 m.

Miles and Kilometres.

Three miles west of Savona, Kamloops lake ends at the broad well-terraced delta of the turbulent Deadman river. The growth of the delta has probably raised the level of Kamloops lake.

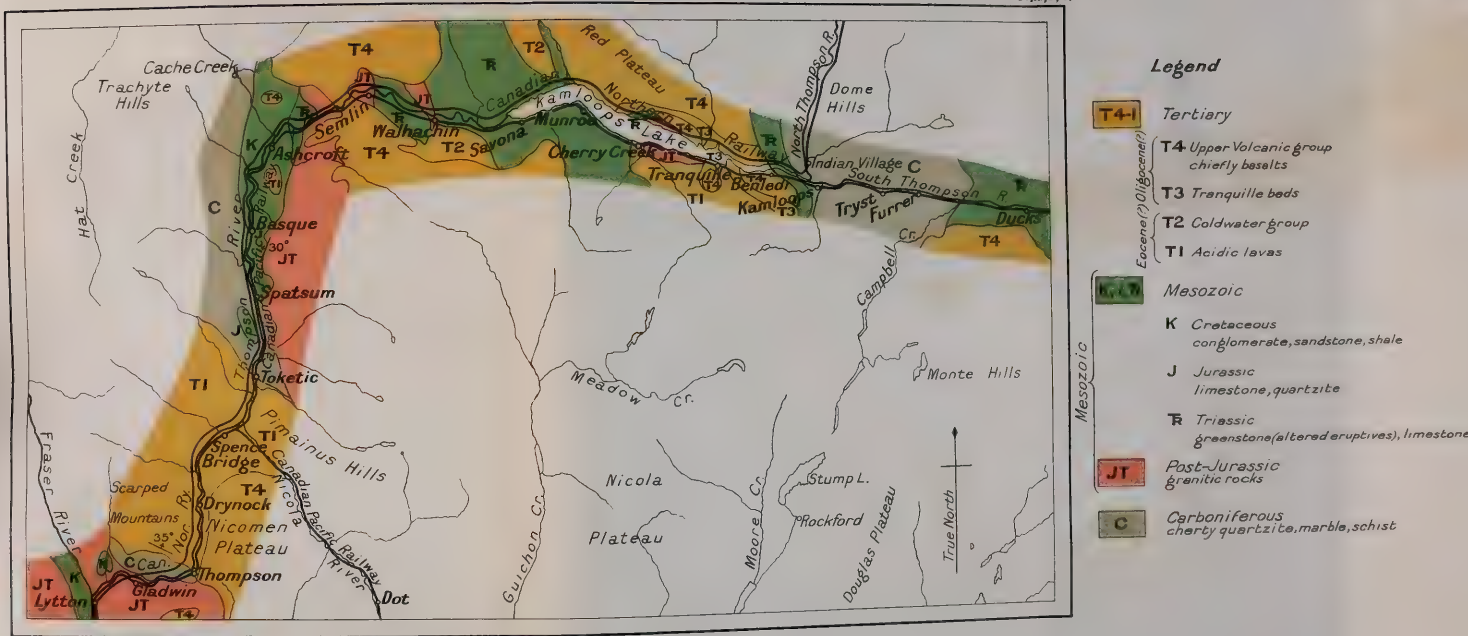
Thompson river here has been forced to the south and bed-rock side of the valley, and from the railroad may be seen the markedly cross-bedded outwash gravels and silts exposed in the high banks across the river.

The valley of Deadman creek with its glacially steepened walls, may be seen extending for more than ten miles (16 km.) northward, where it merges into the lava-capped upland plateau.

The river west of Deadman creek, follows a tortuous course through the thick alluvial valley-fill. Near the 30th mile-post the river makes a prominent horseshoe bend now cut off to form an island and slough across which the Canadian Northern Railway Company are building their line.

32·1 m. **Walhachin**—Altitude 1,252 ft. (381·6 m.).
51·6 km. Walhachin—the centre of an extensive fruit growing district—is situated on the brink of one of the principal fluvio-glacial terraces of the region. The water for irrigation purposes is flumed from Deadman river. The Thompson valley is very wide here, and the river follows a meandering course within it. The result has been a splendid development of broad, gently sloping terraces preserving old meanders and cusps formed by the river at higher levels. Coarse gravel overlying silt, seen from the

C1,2,3,4.



Geological Survey, Canada.

Route map between **Ducks** and **Lytton**

Miles: 5 0 5 10 15 20

Kilometres: 5 0 10 20 30 40

Miles and Kilometres.

train at many places, represents an old river channel.

A broad belt of Coldwater conglomerate, sandstone, and shale outcrops about one mile (1·6 km.) south of the railroad. These sediments represent an old Eocene river course, later uplifted, eroded and protected from further erosion by remnants of younger lava flows.

The train after leaving the Walhachin terraces, winds around points of Triassic rocks and through alluvial fans built up by tributary creeks, until it reaches the 37th mile-post, where a granitic boss is encountered. The granodiorite extends across the river east of Eight Mile creek, and, a couple of miles north, disappears under the lava cap of the Kamloops volcanic group.

38·4 m. **Semlin**—Semlin is a railroad siding named
61·7 km. from the broad, hanging Semlin valley which joins the main Thompson valley at this point. The Semlin valley is probably an old course of Bonaparte creek.

A short distance west of Semlin station, the railroad cuts through the basal portion of a syncline in the Kamloops volcanics. The syncline, which is a continuation of the Savona mountain remnant, extends northward across the river where it widens out into a broad synclinal belt capping the hill tops. The sequence of the rocks as exposed in the rock cuts, shows lavas of trachytic habit, succeeded above by basaltic lava with columnar jointing. The basalt passes into a dense bluish-black phase with pronounced ball-and-socket jointing. The lava passes upward into grayish tuffs and coarse agglomerates containing fragments of basalt. The upland in this vicinity is a peneplain which truncates the slightly tilted Kamloops volcanics. One mile (1·6 km.) west of Semlin, the railroad emerges from the lava syncline and cuts through great thicknesses of alluvial silts, gravels and till. The clay silt is quite consolidated and stands in vertical cliffs forming in many places weird "hoodoos".

Miles and Kilometres.

In one section there is exposed to view about 150 feet (45·7 m.) of clay silt overlain by bouldery till. The alluvium here is underlain by a granodiorite batholith capped by a continuation of the same series of Kamloops lavas.

The contact between the granodiorite batholith and the Jura-Triassic (Nicola) is near the 43rd mile-post at a narrow part of the valley. The Triassic limestones and intercalated sheets of irruptive rock stand out prominently across the river on the southeast flank of Rattlesnake hill, where the series dips about 45° to the northwest.

The Nicola formation is overlapped from the west by Cretaceous conglomerate, shale, and sandstone—a formation which is encountered first at the mouth of Barnes creek, where the Thompson valley broadens out, preparatory to taking a sharp southward bend in its course. Here the river has been forced back upon the delta of Bonaparte creek by the building out of the Barnes Creek delta. The river has cut deeply northward into the fluvio-glacial silts and gravels west of Rattlesnake hill which stand out in prominent cliffs about 300 feet (91 m.) high. In one place, the stratified clay silts are seen contorted and folded into a synclinal trough which is filled by a younger and more sandy silt. The younger silt was probably carried down and deposited subaqueously by Bonaparte creek in what was then a lake. The silts are believed to be of two distinct periods of alluviation contemporaneous with two periods of valley glaciation. The silts may be traced southwestwardly toward the mouth of Bonaparte creek, where boulder clay is found overlying the cross-bedded gravels, sands and silts of the first period of alluviation. The boulder clay is in turn capped by a coarse river bed deposit with a thin layer of silty soil on the surface of the terrace.

47·2 m. **Ashcroft.**—Altitude 996 ft. (303.5 m.).
75·9 km. Ashcroft, "the gateway to the north country", is situated in a wide, level tract of valley land

View showing the character of the topography about Ashcroft.

Miles and Kilometres.

underlain by the readily eroded Cretaceous rocks. The terraced alluvial filling of the valley, where irrigated, is very fertile and produces large crops of potatoes and other vegetables.

From the train one sees terraced outwash Glacial materials skirting the hills of Cretaceous rock which are for the most part capped by Tertiary lavas. The lavas of the mesa-like hills are vesicular and amygdaloidal basalts similar to those at Savona mountain. The main type is a dense, bluish-black basalt showing splendid ball-and-socket, as well as columnar jointing. On the hill seen from the railroad a few miles to the southeast of Ashcroft, this basalt is found capping unconformably a remnant of rhyolitic lava of probably Eocene age.

The topography in this portion of the Thompson valley on account of the semi-arid nature of the climate, approaches the 'bad land' type. The hillsides are dissected by numerous small gullies and ravines as a result of intermittent but violent rainfall.

One half mile south of the 50th mile-post, after passing through the great landslide of October, 1881, a gravel cut shows boulder clay of the first period of valley glaciation, which here underlies the clay silt and gravels deposited during a later alluviation stage of the same period. The railroad cuts through fissile Lower Cretaceous argillites dipping steeply to the west. The rocks at the western border of the Ashcroft Cretaceous are more folded and disturbed than those at the eastern border where they appear to overlap the Jura-Trias rocks. The total thickness of the formation is about 5,000 feet (1524 m.). A coarse basal conglomerate and grit member of the Lower Cretaceous is exposed in the rock cut immediately north of the Black Canyon tunnel.

52·5 m. 84·4 km. **Black Canyon**—The Thompson river here has incised itself, not only through a great thickness of alluvium, but has also cut more

Miles and Kilometres.

than 200 feet (60 m.) deep into the bed-rock itself. This bed-rock is black Cretaceous shale and sandstone. On account of the sombre appearance of the rocks, the gorge is known as the Black Canyon.

To the east of the southern portal of the tunnel may be seen typical mud-slide ground. The ground creeps and forms gaping fissures. Where material has broken away to form landslides, steep bluffs remain. These slides and creep of the ground have caused the railroads much trouble and expense.

About two miles (3·2 km.) below the Black Canyon, the Cretaceous conglomerate (largely granitic) grades down, within a few feet, into an angular breccia, which rests unconformably upon the Nicola rocks.

54·6 m.
87·8 km. **Basque**—Opposite Basque siding the Cretaceous ends, and the underlying Paleozoics (Cache Creek formation) appear for the first time. A few miles west of the river may be seen Red hill, named on account of the highly coloured character of the rocks which compose it. The pyritic cherts and sheared rhyolites of the Cache Creek group have been weathered so as to form red outcrops.

A section of Jura-Trias rocks, intruded by tongues from the underlying granodiorite batholith, may be seen a few miles below Basque.

On nearing Spatsum one may see the west flank of a prominent block mountain composed of Jura-Trias limestones dipping and striking conformably with the slope of the hill. The more resistant, massive Jura-Trias rocks, instead of yielding to orogenic stresses by folding and mashing (like the Cretaceous shales and sandstones), yielded rather by bodily overthrust from the west upon a broad underlying granitic batholith. Clinging to the batholith is a rim of chert due to the contact metamorphism at the time of batholithic intrusion.

60·8 m.
97·8 km. **Spatsum**—Altitude 854 feet (260·2 m.). On the opposite side of the river from Spatsum,

Looking up Thompson valley towards Ashcroft; Spatsum Siding in the bottom of the valley.

Miles and Kilometres.

gypsum and china clay may be seen in crumbling outcrops of red, yellow and white. The highly coloured decomposed material is almost devoid of vegetation.

The Cache Creek formation crosses the river at Spatsum, and extends southward to Toketic, where black argillites and quartzites of this formation pass under the Spence's Bridge Volcanic group.

Between Spatsum and Toketic there are two places to be seen from the railroad where the Jura-Trias rocks rest unconformably upon the Cache Creek formation. The largest outlier is on the west side of the river and forms a high hill separating the Thompson from Venables valley. Venables creek flows through the southern end of the exposure, and has exposed a very fossiliferous section near 89-Mile Stable on the Cariboo road.

The other outlier, which is in a badly metamorphosed condition, outcrops high up on the east side of the Thompson valley above the great rock slide, at the base of which is nestled an Indian village and church. The Jura-Trias is here in contact with the granodioritic batholith and basal Cache Creek rocks.

There are a series of strike ridges and ravines paralleling the cliff face 1,500 feet (457·2 m.) above the railroad. The Jura-Trias metamorphics dip flatly to the west while the underlying Cache Creek rocks, where observable, dip steeply to the east. The Jura-Trias rocks are crevassed along joint planes nearly at right angles to their bedding.

A couple of miles south of the Rock slide at the mouth of Pukaist creek, the railroad cuts transversely through Cache Creek marble, well exposed across the river in the Canadian Northern Railway tunnels.

67·2 m. **Toketic**—Altitude 810 ft. (246·8 m.). At
108·1 km. Toketic a series of volcanic rocks commence which have been correlated and mapped as the Lower Volcanic group (Miocene?) by G. M. Dawson, but regarding whose age there is

Junction of Nicola and Thompson valleys, near Spence's Bridge.

Miles and Kilometres.

much doubt. The writer regards them as Jura-Cretaceous. These volcanic rocks, which continue as far as Thompson Siding, have, for convenience, been named the Spence's Bridge group. They consist of a badly altered series, chiefly of liparitic and andesitic lavas with interbedded conglomerate, arkose and tuff, the latter containing plant remains of Lower Cretaceous and Upper Jurassic age.

A light yellowish member of the Spence's Bridge Volcanic group is prominently exposed below the mouth of Twaal creek, on the west side of the valley, where the river begins to take a westward course. This is a peculiar acidic lava, with spherulites averaging $\frac{3}{8}$ inch (1 cm.) in diameter and having in places pronounced flow structure. The acidic lavas are intruded by basic dykes, possibly the feeders for the younger Miocene basalts.

One mile above Spence's Bridge the broad glaciated valley of the Nicola joins that of the Thompson.

72·6 m. **Spence's Bridge**—Altitude 768 ft. (234·0 m.).
116·8 km. Spence's Bridge, the junction point for the Nicola Valley railroad, is picturesquely situated in Thompson valley at the base of the precipitous Arthur's Seat mountain.

Arthur's Seat, rising abruptly 5,500 feet (1,676 m.) above sea level, is thought to have been one of a series of volcanic vents which were active along the east front of the Coast range in Jura-Cretaceous time. At the base of Arthur's Seat may be seen silt escarpments, from which a large volume of alluvium broke away on Aug. 13, 1905, damming the Thompson river and causing the destruction of an Indian village across the river. Five Indians were buried alive in the slide, ten were killed and thirteen hurt by the wave which swept up the river.

79·1 m. **Drynock**—Altitude 752 ft. (229·2 m.). A
127·2 km. few miles below Spence's Bridge, the narrowing valley swings southward and maintains a

Miles and Kilometres.

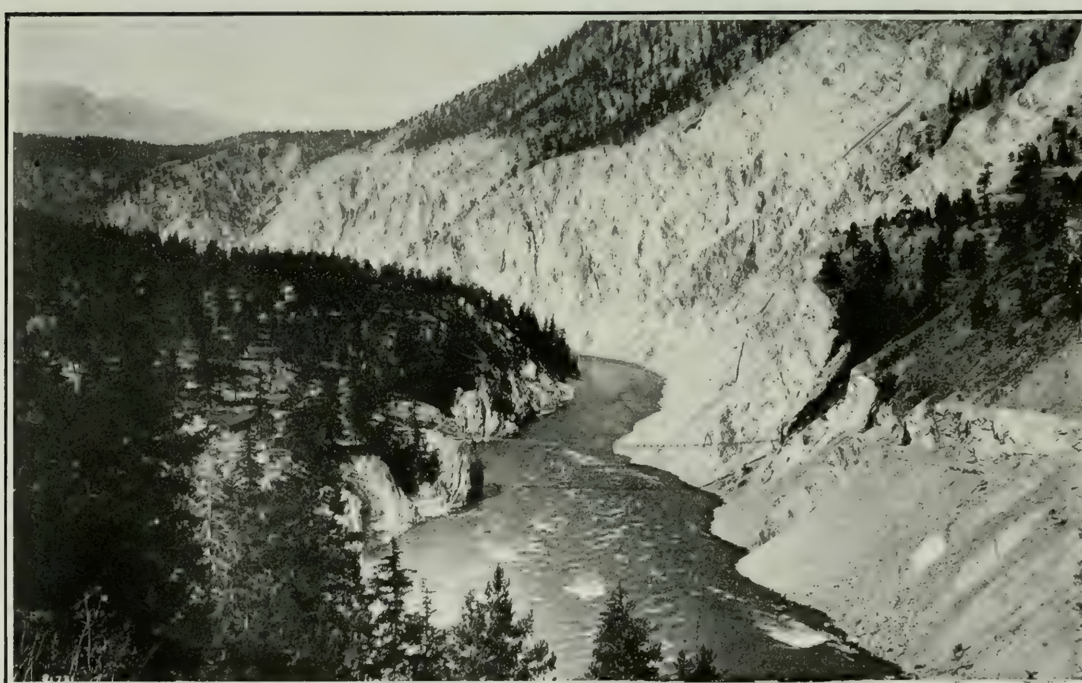
southward course until it reaches Thompson Siding.

The Spence's Bridge Volcanic group is capped a few miles northeast of Drynock by typical basalt of the Kamloops Volcanic group. About 100 feet (30·5 m.) of tuff beds, resembling the Tranquille beds, are present at the contact.

85·3 m. 137·2 km. **Thompson Siding**—Altitude 670 ft. (204.2 m.). At Thompson Siding, the Nicoamen river tumbles over a waterfall to unite with the Thompson which here bends sharply, taking a west course until it reaches the Fraser river at Lytton. The first discovery of gold in British Columbia is said to have been made by an Indian at the mouth of the Nicoamen in 1857. As the train rounds some of the rocky bluffs on the south side of the Thompson Canyon, an occasional glimpse of the snowclad Stein Peak and other Coast Range mountains may be had. The scenery through this canyon portion of the Thompson valley is rugged and mountainous, with huge talus blocks scattered along the channel of the river. There is comparatively little Glacial silt in this portion of the valley. The post-mature upland of the summits grades gradually into the alpine topography of the Coast range. As the train winds through higher upland country, there is a marked increase in the depth of the tributary valleys beneath its surface.

Westward of Thompson, the railroad cuts into highly pyritic quartz schists before entering the eastern border of the Coast Range batholith.

89·7 m. 144·3 km. **Gladwin**—Altitude 745 ft. (227·0 m.). A contact zone between the Coast Range batholith and Paleozoic schistose rocks, the whole traversed by many Tertiary dykes and chonolithic intrusions, is exposed on the steep scarped north wall of the canyon between Gladwin and Lytton. A few miles further west, near the mouth of Botanie creek, is an odd granitic ridge named 'The Crag.' It is cut off sharply to the west by a fault scarp which gives a very irregular outline to the hill. The eastern side



Scarped north wall of Thompson canyon near Gladwin.

Miles and Kilometres.

has a relatively gentle slope, dotted with evergreens.

A small detached area of Cretaceous shale, sandstone and conglomerate, all much disturbed, occurs near the mouth of Botanie creek about two miles (3·2 km.) from Lytton.

From Lytton mountain, which rises about 6,000 feet (1,829 m.) southeasterly above the town, may be seen on a clear day, the Cascade mountains in Washington, and similar rugged alpine summits supporting glaciers and névé fields in the Coast range.

COAST RANGE (Lytton to Vancouver)

BY

CHARLES CAMSELL.

INTRODUCTION.

From Lytton to Vancouver, a distance of 156 miles, (251 km.), the route of the excursion follows the valley of Fraser river. This stream, discovered and explored by Simon Fraser in 1808, is the largest stream in British Columbia whose basin lies entirely within the boundaries of the province. It has a length of 790 miles (1,271 km.) and drains an area of 91,700 square miles (237,686 sq. km.) Rising on the western slope of the Rocky mountains in latitude 53° N., it first flows northward in the great structural valley known as the Rocky Mountain trench until it reaches latitude 54° 15′ where it bends with a wide curve to the west and then to the south. From Fort George its course is almost due south until it reaches Hope, where, in turning westward, it breaks through the mountains bordering the Pacific coast and within 100 miles (161 km.) empties into the Strait of Georgia.

In its course from Lytton to the sea the Fraser traverses two strongly contrasted types of physiographic form, one the rugged mountainous region of the Coast and Cascade Mountain systems, and the other the comparatively level region of the delta. The former of these two physiographic

units comprises a broad mountainous belt lying between the Interior Plateau region and the coast, which has an average width of about 100 miles (161 km.), and a length in Canada of about 900 miles (1,448 km.) It is made up largely of a composite mass of plutonic igneous rocks called the Coast Range batholith, which has been thrust through, and is flanked by, Paleozoic and Mesozoic sediments, blocks of which have been engulfed and are infolded in it.

Looking southwest from Mt. Ferguson, Lillooet district, showing mountains typical of the Coast range.

The delta portion is relatively small and in Canada has an area of over 1,000 square miles (2,592 sq. km.) though it also extends southward into the State of Washington. It is floored by Eocene deposits of estuarine origin which are covered by more recent Glacial and post-Glacial materials.

COLUMNAR SECTIONS.

(By N. L. Bowen).

Eastern part (Lytton to Hope).

Pleistocene and Recent—Till, stream gravels, etc.
Unconformable relation.

Lower Cretaceous—Jackass Mt. series.	*Erosion surface.* Conglomerate, 2,000 ft. (609 m.). Black shale, with marine shells, 500 ft. (152 m.). Green and grey arkoses, with plant remains; 300 ft. (91 m.). *Base not exposed.*

Unconformable relation.

Lower Mesozoic—
Boston Bar group—Thin-bedded grey argillites.
Palæozoic—
Câche Creek group—Cherty argillites, limestone, quartzite, serpentine; thickness and order of succession indeterminate.

Western part (Hope to Vancouver).

Quaternary—Till, stream gravels, etc.
Unconformable relation.

Eocene..........	Basaltic and andestic lavas. Conglomerates, grits, shales with plant remains; 3,000 ft. (914 m.).

Unconformable relation.

Lower Cretaceous?—Quartz porphyry flows.
Unconformable relation.

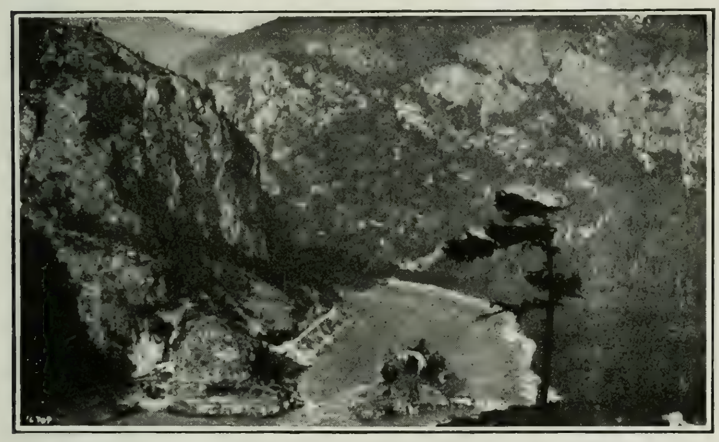
Palæozoic—Agassiz series—	Limestone, 1,000 ft. (304 m.). Black shale, 3,000 to 4,000 ft. (914 to 1,219 m.). Conglomerate, 3,000 to 4,000 ft. (914 to 1,219 m.).

The above sections do not include the granitic rocks, which are apparently of two ages, Jurassic and post-Lower Cretaceous. The older rocks are usually gneissic and sometimes sheared, and include both granodiorites and granites. The younger rocks are always fresher and never gneissic, and usually more acid than the older type. They are dominantly hornblende-rich, in contrast to the older type in which the hornblende is subordinate to a greenish biotite.

THE CANYON OF FRASER RIVER.

Physical Features.

Above Lytton the Fraser flows through the Interior Plateau region, but from that point down to the head of the delta below Hope it is closely hemmed in by the high mountains of the Cascade range on the one side and of the Coast range on the other. These two mountain systems overlap each other for about 100 miles (161 km.) and in



Entrance to Fraser canyon above Yale, with Lady Franklin Rock in the middle of the stream.

the break between the over-lapping edges the river forces a difficult passage until it eventually emerges from them at the head of the delta, to pass around the southern end of the Coast range. This part of Fraser valley is, properly speaking, the canyon of the river though it has become customary when speaking of "Fraser Canyon" to refer to an inner gorge-like constriction 25 miles (40 km.) in length extending from North Bend to Yale.

Throughout its length the main canyon is deep and bordered by mountains which in places reach an altitude of 7,000 feet (2,133 m.) above the sea. The sides of the valley are generally rocky and steep, though the degree of slope varies with the nature of the rocks in which it is cut. For example, it is narrow and very steep-sided where

located in granitic rocks, and broader and more open where the bed rock is the more easily eroded sedimentary rocks. In cross-section it is more or less U-shaped from the effect of valley glaciation.

In the wider portions of the main canyon gravels have accumulated to a considerable depth, but in the more constricted parts deposits of this nature are rare and of very limited extent. The gravels were deposited in the closing stages of the Glacial period, but as a result of later deepening of the stream bed a large part of them has been removed and the remainder left as terraces, marking successive stages in that deepening. As many as a dozen terraces can be counted in the valley at Lytton. Uplift since Glacial times has given the stream such renewed power of erosion as to cause it to cut down not only through the sands and gravels, but even to deepen its bed into the solid rock, leaving rock benches here and there on one side or other of the valley bottom. Benches of this nature are noticeable at Spuzzum and near Saddle Rock.

The grade of the stream varies from about 4 feet to the mile (·76 m. per km.) in the portions above and below the inner canyon to 8 feet to the mile (1·52 m. per km.) in the inner canyon itself.

Virtually all the streams tributary to the Fraser river along the main canyon, and particularly those of small volume, enter through hanging valleys. The development of the hanging valleys is in the main due to glaciation though in one or two instances the hanging valley effect is heightened by post-Glacial deepening of the main stream itself.

GEOLOGY.

Stratified rocks of Carboniferous age (Cache Creek) consisting of cherty quartzites, argillites, limestones, serpentine and volcanic flows are the oldest rocks in the main canyon. These rocks have been greatly disturbed and now dip at high angles, striking diagonally across the river. They have been in part intruded by granitic rocks and in part covered by later stratified rocks so that they now have a small areal extent.

Plutonic igneous rocks, mainly granodiorite, are exposed throughout a great part of the main canyon, especially in the gorge below North Bend. They belong to the great

Coast Range batholith, and while the major portion of them is of Jurassic age, some are believed from their structure, to be post-Lower Cretaceous. These rocks, especially the older ones, show shearing and faulting and have two well developed lines of fracture, namely N. 15°W. and N. 20° E., which to a considerable extent influence the direction of the stream. From Yale to Hope they are traversed by a wide shear zone striking north and south, and along this the stream has directed its course.

Lower Cretaceous rocks occupy the valley of the river below Lytton, and appear as erosion remnants near Hope; they consist of conglomerate, slate and sandstone, which contain a few marine fossils.

No deposits of Tertiary age occur in the main canyon, though in the delta immediately below there is a great thickness of Eocene beds, and in the region above the canyon are Oligocene sediments, associated with volcanic flows.

Glacial deposits of till, sand, and gravel fill the lower parts of the valley wherever they have found space for lodgment. They have been carved into terraces by the stream, and more recent deposits of gravel have been formed. These recent gravel deposits are the high-grade gold-bearing placers which caused a great influx of placer miners to the region in 1858 and the years following, and from which many millions of dollars worth of gold have since been won.

ORIGIN AND HISTORY OF FRASER CANYON.

The origin and history of Fraser canyon are by no means clear. In attempting to work them out, one need not go farther back in geologic time than the revolution following the deposition of the Lower Cretaceous rocks. It is clear from the geology of the region that during Lower Cretaceous times no stream could have existed along the present course of the river, for the region of the canyon was at that time a geosynclinal basin occupied by an arm of the sea. This region was however elevated into a land area in later Cretaceous times. The development of drainage systems must then have begun in this region, and among them very probably that of the Fraser river, for reasons which follow.

It is generally conceded by all who have worked in the central part of British Columbia that the development of the plateau features of the interior were initiated by long continued erosion acting throughout Eocene times. The enormous amount of material eroded during this period must have been carried away by streams and deposited elsewhere, and the only considerable development of Eocene beds in that part of the continent is found in the delta of the Fraser river and in the neighbouring parts of the State of Washington. The structure of these beds indicates clearly that they were laid down as delta deposits in an estuary of the sea; while in shape they have here a deltoid arrangement with the apex of the delta pointing up Fraser valley towards the lower end of the canyon. The shape of these Eocene deposits suggests that the stream, which carried the material of which they are composed, had its outlet at or near the lower end of the present canyon and it is probable that the course of that stream was along the present course of the river at least as far as the Interior Plateau region. This evidence, however weak, is the first that we have of any stream existing along the present course of the Fraser river.

However, G. M. Dawson, who has studied the history of Fraser river above the canyon, reached the conclusion that the course of the river, as it exists to-day in the plateau region, was only defined since the deposition of certain flat-lying Miocene or Oligocene beds, through which the river now cuts. Those beds however could have been deposited in a lake or an expansion of the river where still-water conditions prevailed along its course.

The selection of the course of the stream along its present lines has been governed largely by the structure of the rocks through which it flows. For example, for 8 miles (12·8 km.) below Lytton it flows in a band of Lower Cretaceous rocks which have been down faulted against the granite rocks and beyond this it follows closely the contact of these Lower Cretaceous rocks with the underlying Palæozoic formation as far as North Bend. Also, in the gorge below this, though the trend of the valley is in the main due south, in detail the course of the stream has two well defined directions which correspond to two lines of weakness in the granite rocks in which it is cut. These two lines of weakness strike N. 20° E. and N. 15° W. Below the gorge also the valley is carved out along structural

lines in the bed-rock formation. The canyon of Fraser river is therefore a subsequent valley and is developed as a result of rock structure. The composition of the rocks, however, has had a marked determining effect on the shape of the valley, for it is wide in the soft sedimentary rocks and sheared granitic rocks but is narrow in the massive igneous rocks.

Fraser river, looking down from Yale; valley here widened out on greatly sheared granite of the Coast Range batholith.

If the course of Fraser canyon was defined in Eocene times it is very likely that it has followed the same channel down to the present, for the Eocene beds of the delta show that there was no great structural disturbance, even in Miocene times, in that part of the valley, such as might cause the stream to shift its course. The absence of Miocene and Pliocene delta deposits does not necessarily disprove the idea that the stream persisted along that course throughout those periods, because deposits of those ages were probably carried farther out to a point now covered by the sea before they came to rest, or if deposited sooner have since been eroded away. It is more than likely, therefore, that, having defined its course in Eocene times, the Fraser has persisted along that course down to the present.

Long-continued erosion, acting throughout the early and middle Tertiary, must have produced, by the beginning

of the Pliocene period, a fairly mature valley with wide, flaring sides, and a floor several hundred feet above the present stream bed. A well defined topographic break on the slope of spurs projecting into the valley 1,500 (457 m.) to 2,000 feet (784 m.) above the present stream bed may mark the old valley slope. When the Pliocene uplift took place, elevating the Cascade range and the adjacent part of the Coast range, the stream was revived and the deepening of the gorge was begun.

At the close of the Pliocene the canyon was problably sharper than the present canyon with, however, the same variations in character due to the relative resistance of the rock formations Glaciation subsequently widened the bottom of the valley to its present shape.

At the close of the Glacial period the land was depressed below its present level and unconsolidated deposits of sand and gravel were laid down in the bottom of the valley to a depth of several hundred feet.

Elevation of the land in relation to the sea has since taken place, and the erosive power of the stream has again been revived. It has consequently cut down through the Glacial deposits. leaving a series of terraces at different levels to mark successive stages in the deepening of the valley. In the gorge, deepening has progressed through these Glacial deposits and into the solid rocks below to a depth of about 100 feet (30·5 m), leaving remnants of the old valley floor as rock benches on one side or the other of the stream. The amount of uplift appears to have been greater in the interior than on the coast.

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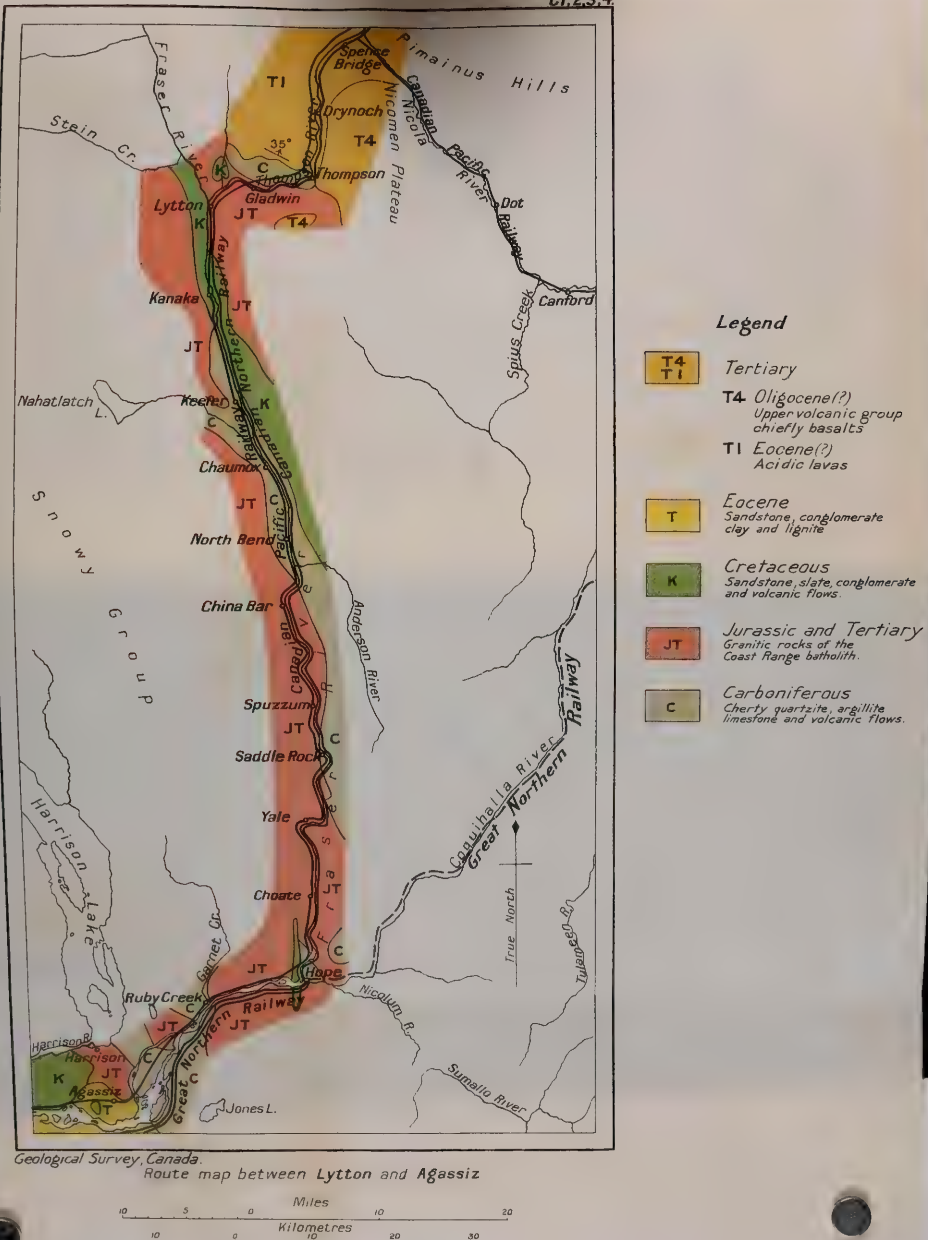


Geological Survey, Canada.

Route map between **Lytton** and **Agassiz**

ANNOTATED GUIDE.

(Lytton to Agassiz).

Miles and Kilometres. (From Lytton.) **Lytton**—Alt. 687 ft. (209. 3m.). The Thompson river empties into the Fraser at the town of
0 m. Lytton, and from this point westward to the
0 km. Pacific coast the railway follows the course of the Fraser river, which for about 80 miles (129 km.) cuts a deep canyon-like valley through the mountains bordering the coast, and afterwards flows for 70 miles (112 km.) through a delta of its own construction to the sea. In the neighbourhood of Lytton a series of well developed river terraces can be seen in the lower part of the valley. These terraces mark successive stages in the deepening of the valley since the deposition of drift material in the closing stages of the Glacial period.

For eight miles (12·8 km.) below Lytton the rocks in the immediate neighbourhood of the railway are of Lower Cretaceous age striking nearly parallel to the river and dipping at low angles. To the west these rocks are in contact with granitic rocks against which they are down faulted. The attitude and structure of the Cretaceous rocks is well shown at the bridge near Cisco, where the railway crosses to the west side of the river. There also a tunnel cuts through the fossiliferous black shale of this series.

8 m. **Kanaka**—Alt. 623 ft. (189.8 m.). At
12·8 km. Kanaka a belt of Palæozoic rocks appears to the west of the river and for a few miles southward the river follows the line of contact between these rocks and the Lower Cretaceous. About three miles (3·2 km.) below Kanaka, Jackass Mountain, which is made up of massive conglomerates overlying black shale, rises as a long steep bluff from the water edge. In the course of building a line along the face of the bluff the Canadian Northern railway company has been seriously handicapped by rock slides

Miles and Kilometres.

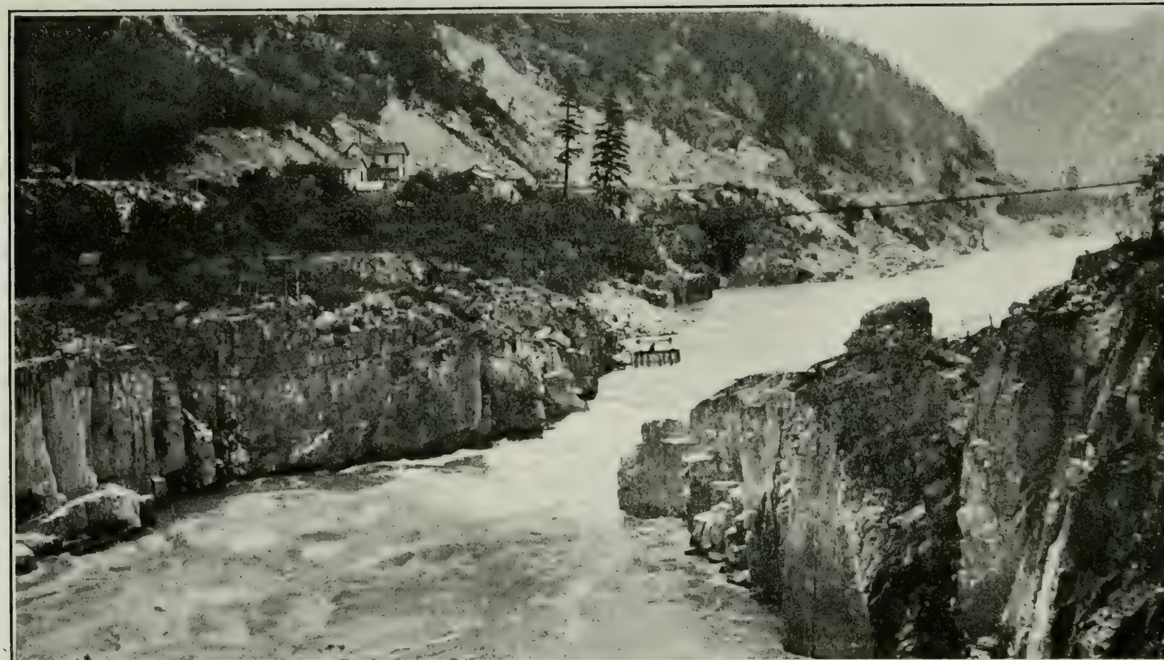
which have left great gashes in the side of the mountain.

14 m. 22·5 km. **Keefers**—Alt. 555 ft. (169m.). Near Keefers and below it the Palæozoic rocks occupy both sides of the valley and continue to a point three miles (4·8 km.) below North Bend.

27 m. 43·4 km. **North Bend**—Alt. 487 ft. (148 m.). About two miles (3·2 km.) above North Bend the banded grey argillites of the Boston Bar series appear. These rocks have yielded Dr. Bowen a single, definitely Mesozoic fossil. Since they are cut by the late Jurassic granites, they are either Jurassic or Triassic in age. Much placer gold mining was at one time carried on in this part of Fraser valley, and the evidence of such work is still to be seen in many places, particularly at Boston Bar, a mile below North Bend. Three miles (4·8 km.) below North Bend, the Palæozoic sedimentary rocks are intruded by granitic rocks of the Coast Range batholith. The contact however is not a clean-cut line of separation between the two formations, but is rather a wide zone marked on the side of the intruded rocks by numerous apophyses of the igneous rocks in the sedimentary, and on the side of the batholith by inclusions of the Carboniferous rocks in the batholith. The zone of apophyses is well shown in the railway cuts on the west side of the river.

32 m. 51·5 km. **China Bar**—Alt 466 ft. (142 m.). Turning a sharp bend in the course of the valley four miles (6·4 km.) below North Bend, the railway enters what is popularly known as "Fraser Canyon," a narrow rock-walled gorge in the main canyon, cut into the massive granitic rocks of the Coast Range batholith, which here form the axis of both the Coast and Cascade Mountain systems. The gorge has a length of 25 miles, (40·2 km) and though a serious barrier both to water and land transportation, it forms the only natural route of travel between the coast and the interior of British Columbia.

Although referred to as a canyon for the whole 25 miles (40·2 km.) of its length it is



Constriction of Fraser river at Hell's Gate near China Bar. The ledges are composed of jointed granodiorite.

Miles and Kilometres.

not uniformly canyon-like throughout, but is rather a succession of narrow gate-like constrictions connecting somewhat broader expansions of the river. Through these narrow passages the water rushes with greatly increased velocity and tremendous force, swirling and eddying from wall to wall and forming such a confusion of currents as to make the navigation of these gaps exceedingly hazardous in low water and absolutely impossible in a high stage. Hell's Gate, Black Canyon, and Chaquama Canyon are among the most remarkable of these constrictions, the first and last mentioned each having a width of about 200 feet (61 m.).

For almost its entire length the gorge is cut into granitic rocks of medium acid composition, the predominating type of which is a gneissic granodiorite. Though the larger proportion of these rocks is of Jurassic age, some are considerably younger and from their structure and lack of metamorphism are probably of early Tertiary age. These younger rocks are easily identified even from a distance by their well developed and regular places of jointing; because of this characteristic they have been used to a large extent by the railway companies in the lining of tunnels and in other types of masonry.

Skuzzy creek, a roaring torrent, plunges out of a hanging valley into the Fraser river at China Bar near the upper end of the gorge. On the opposite side of the river in a steep bluff can be seen a network of light-coloured aplite dykes traversing the granodiorite. The stream here runs in an almost direct line southward, gradually becoming narrower until two miles (3·2 km.) below, it rushes through Hell's Gate between vertical walls of massive jointed granodiorite.

43 m. **Spuzzum**—Alt. 395 ft. (118·8 m.). Beyond
69·2 km Hell's Gate the railway enters a succession of tunnels cut through projecting bluffs of rocks in a moderately wide part of the valley, on

Miles and Kilometres.

passing which the valley again narrows quickly to the constriction called "Black Canyon". Here, as elsewhere throughout the length of the gcrge the line of the Canadian Northern railway can be seen under construction on the opposite side of the river. A number of bridges slung on wire cables and used by the builders of that line span the river in several places. The remains of the old Alexandra Bridge, where the historic Cariboo road crossed the river, can still be seen two miles (3·2 km.) above Spuzzum. The Indian village of Spuzzum, a mile below the station of the same name, is built on a delta fan of Spuzzum creek.

Saddle Rock—The valley widens again at Saddle Rock where it passes over for at short distance from the batholith into tilted Carboniferous rocks. At Saddle Rock, and a "Chaquama Canyon" 2 miles (3·2 km.) below, where the stream is only 200 feet (60·9 m.) in width for a distance of 1,000 feet (304·8 m.), rock benches have been developed on the west side of the valley as a result of post-Glacial deepening. A number of shorter constrictions follow in the next 4 miles (6·4 km.). One mile and a half (2·4 km.) before reaching Yale the valley seems closed altogether and no outlet is visible. The stream, however, takes a sharp bend to the west, and after flowing around Lady Franklin Rock, it suddenly emerge into a broader open valley and the gorge is left behind.

54 m. 86·9 km. **Yale**—Alt. 215 feet (65·5 m.). Yale is one of the oldest places on the Fraser river, having been established by the Hudson's Bay Company as a trading post in 1856, and was a place of considerable importance in the early days of the gold excitement in Cariboo. From this point down to Hope, the valley of the river lies in a wide shear-zone in an acid granite, forming a phase of the Coast Range batholith; in consequence of this its width is greater than that which obtains in the gorge. The white cliffs

Miles and Kilometres.

seen in the west side of the valley near Emory creek show the effect of this shearing.

Choate—

65 m. 104·7 km. **Hope**—Alt. 209 feet (63·6 m.). Looking directly down the valley from Yale, a high mountain fills the view and at the base of this is the town of Hope, from which point the old Dewdney pack-trail, once the main highway to the interior of the Province, runs eastward over the mountain ranges. The Paleozoic rocks are again in evidence at Hope, and on them rest patches of Cretaceous conglomerate, remnants of a larger synclinal basin which once stretched southward, across the International Boundary line.

75 m. 120·7 km. **Ruby Creek**—Alt. 96 feet (29·3 m.). Half a mile beyond Hope, a younger massive hornblende granite appears, and from here down to Agassiz at the head of the delta of the Fraser, this is the prevailing rock, though occasionally as at Ruby creek one sees exposures of the Carboniferous rocks.

"The relationship of the later hornblende granites to these sediments is particularly well shown. Where the unroofing of the granite is rather far advanced, it appears as fairly regular masses elongated in a northwesterly direction and therefore cutting across the strike of the sedimentary rocks. Beds are truncated sharply, but appear again on their strike, across a width of two or three miles of granite, quite as if no interruption had taken place. Where unroofing is still imperfect, granite occupies the lower slopes of the hills and is capped by the bedded rocks. These receive numerous dykes and sills from the granite beneath, but preserve their strike and dip entirely intact. In short, there is shown most convincing evidence of replacement, rather than displacement, of the sediments by the invading magma." (N. L. Bowen.)

Although the trend of the valley is now directly across the strike of the mountain axes, the

Miles and Kilometres.

width increases gradually, the mountains, particularly on the southeast side, retreating farther and farther back. The grade of the river also changes and is reduced from eight feet to the mile (1·52 m. per km.), which it held in the gorge, to about three feet to the mile (·57 m. per km.). The vegetation, too, becomes typical of the Pacific coast and shows the effect of a moist, warm climate on a rich soil.

86 m. 138·4 km. **Agassiz**—Alt. 54 ft. (16·5 m.). Agassiz is virtually at the head of the Fraser delta. Five miles (8 km.) to the north, at the southern end of Harrison lake, is the hot spring known as St. Alice's well. The waters, which contain a large percentage of sodium and some potassium sulphate, rise with a temperature of 150° F. out of the crevices in Cretaceous rocks near the contact of a later hornblende granite. The springs probably represent the last traces of volcanic forces which were once active in this part of the Coast and Cascade mountains and of which Mt. Baker, to the south, is such a striking witness.

FRASER DELTA.

Topography.

The delta of the Fraser river is compound in structure and was built up at different times, beginning with the Eocene. Its construction was continued at the close of the Glacial period and is being carried on at the present time. The region embraced within this compound delta extends from Agassiz westward to the Pacific coast and runs southward across the International Boundary line. To the east it abuts against the Cascade range, and its northern boundary is the Coast range, while its southern limit is in the State of Washington.

The topography of the delta is in the main low and fairly level, with elevations ranging from sea level to about 400 feet (122 m.) above it. However, here and there in the upper part an isolated hill stands above the general level, reaching an altitude of about 1,000 feet (304·8 m.) above the sea. Sumas and Chilliwack mountains are typical examples of the higher eminences.

Geology.

The oldest exposed rocks are the granitic rocks of the Coast Range batholith, which border and underlie the delta on the north.

Remnants of once more extensive Lower Cretaceous rocks form some of the hills in the upper part of the delta, and around these the more recent deposits were laid down.

Virtually the whole of the delta, with the exception of those parts covered by the Cretaceous remnants, is believed to be floored by stratified rocks of Eocene age, which are referred to in the literature as the Puget group. They consist of little disturbed beds of conglomerate, sandstone and shale which were laid down by the ancient Fraser river in an estuary of the sea. They have a thickness of about 3,000 feet in Canada, but are much thicker in the State of Washington. They contain a variety of plant remains and some small seams of lignite.

The Eocene beds suffered erosion throughout the remainder of Tertiary times, but towards the close of the Glacial period were overlaid throughout by sands, gravel and till. These deposits now constitute broad, flat-topped plateaus about 400 feet (122 m.) high, which were once continuous as the late Glacial delta of the river. They have, however, since been dissected by the present stream, as a result of post-Glacial elevation. This process of dissection is related to the strong terracing of the Glacial deposits in the upper part of the Fraser river.

A modern delta is at present being formed by the river and pushed seaward into the Gulf of Georgia.

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ANNOTATED GUIDE.

(Agassiz to Vancouver).

Miles and Kilometres.

95 m. 152·8 km. **Harrison Mills**—Alt. 40 ft. (12·2 m.). From Agassiz to the coast the railway runs through the agricultural country of the delta, which is everywhere covered with deep alluvium and, in consequence, rock exposures are rare. The whole delta is believed to be floored by deposits of Eocene age, which are covered by Glacial and post-Glacial deposits of the same character. Knobs of granitic rocks and Lower Cretaceous quartz porphyries project through the more recent deposits.

Harrison river is crossed at Harrison Mills, and beyond, the railway curves around and behind an outlying knob of these granitic rocks.

Hatzic—Alt. 30 ft. (9·14 m.).

114 m. 183·4 km. **Mission**—Alt. 21 ft. (6·4 m.).

Silverdale.

As far down as the sea coast the railway skirts the southern base of the Coast Range mountains, which are composed of the granitic rocks of the Coast Range batholith. Occasionally cuts are made into projecting points, which show their character. At Silverdale a part of the old floor on which the Eocene delta deposits were laid down is exposed. This floor is presumably part of the Coast Range batholith, and its deeply weathered character indicates that it was long exposed to the action of weathering before the deposition of the Eocene deposits. The irregularity of that old floor, and the attitude of the Eocene deposits in relation to the adjacent mountains, suggest also that during the deposition of those deposits the neighbouring region of the Coast range was then, as now, one of considerable relief.

Ruskin—

130 m. 209·2 km. **Haney**—Alt. 19 ft. (5·8 m.).

Miles and Kilometres.

132 m. 212·4 km. **Hammond**—Alt. 21 ft. (6·4 m.). At Ruskin the Fraser is joined by Stave river. Six miles (9·6 km.) up the latter valley is a hydro-electric plant, generating at present 26,000 horse-power. Exposures of post-Glacial stream deposits are now frequently seen in the railway cuts. These stand at a level of 40 feet (12·2 m.) or more above the present level of the stream.

140 m. 225·3 km. **Westminster Junction**—Alt. 28 ft. (8·5 m.).

144 m. 231·7 km. **Port Moody**—Alt. 13 ft. (3·9 m.). Crossing Pitt river near Westminster Junction, the railway leaves the Fraser river and passes over a low divide to the head of Burrard inlet, the southern shore of which it then follows to Vancouver.

147 m. 236·5 km. **Barnet**—

Hastings—

156 m. 251 km. **Vancouver**—

In the cliffs along the shore of Burrard inlet good exposures of the Eocene beds may be seen. These deposits have been proved by borings to rest directly on the rocks of the Coast Range batholith, and to have a thickness under the City of Vancouver of several hundred feet. They consist of sandstone, conglomerate and clay. They have the structure of delta deposits and were probably deposited in the delta of the ancient Fraser river. They are well exposed in the sea-cliffs at Stanley Park, where also they are intruded by dykes of porphyrite.

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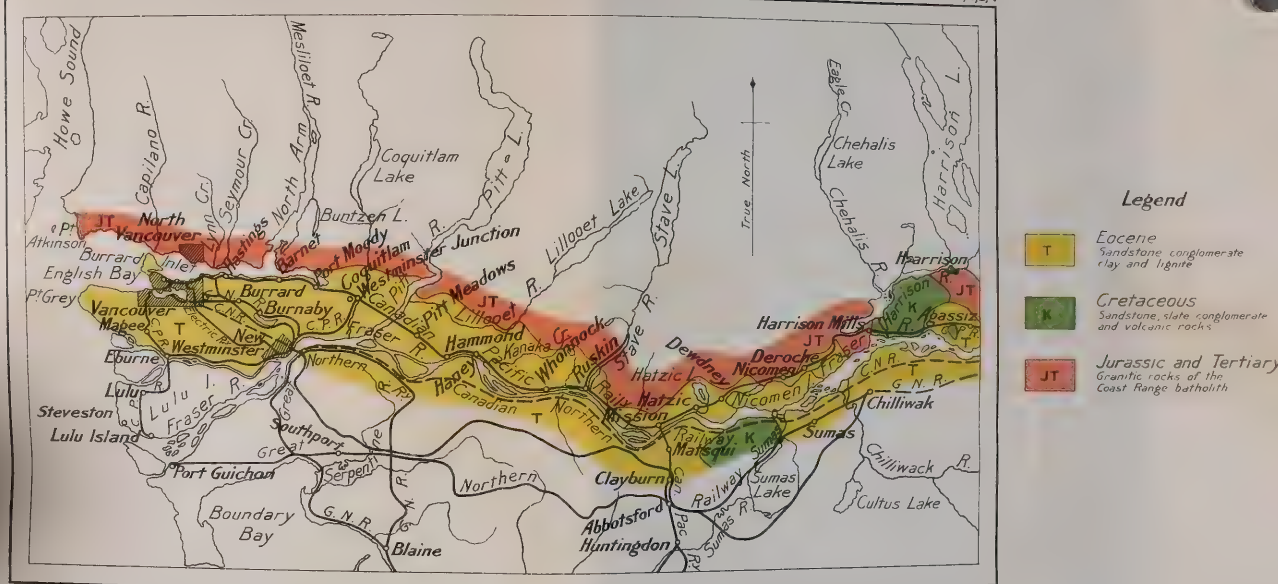

Geological Survey, Canada

Route map between **Agassiz** and **Vancouver**

Miles

10 5 0 10 20

Kilometres

10 5 0 10 20 30

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Canada. Geological Survey
Guide book[s of excursions in Canada]

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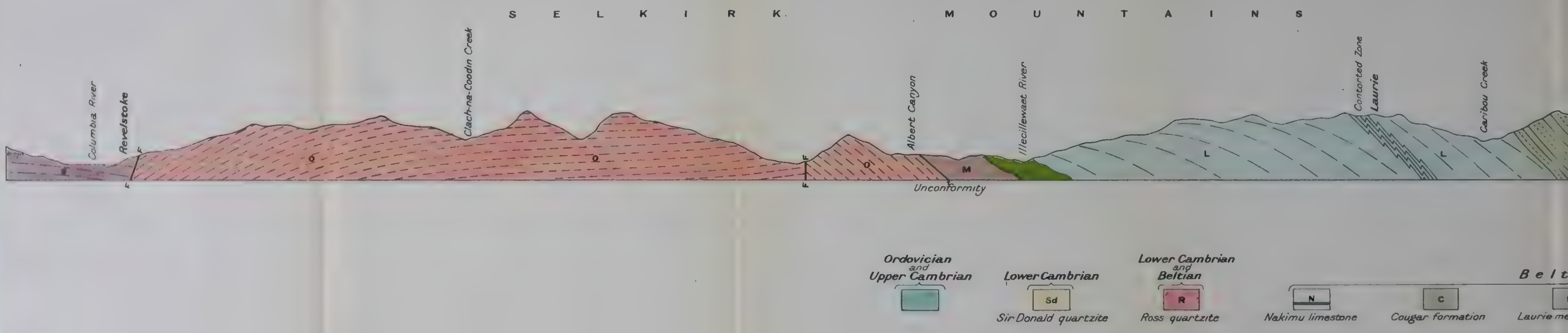

Geological Survey, Canada

Structure Section of the Selkirk and Purcel

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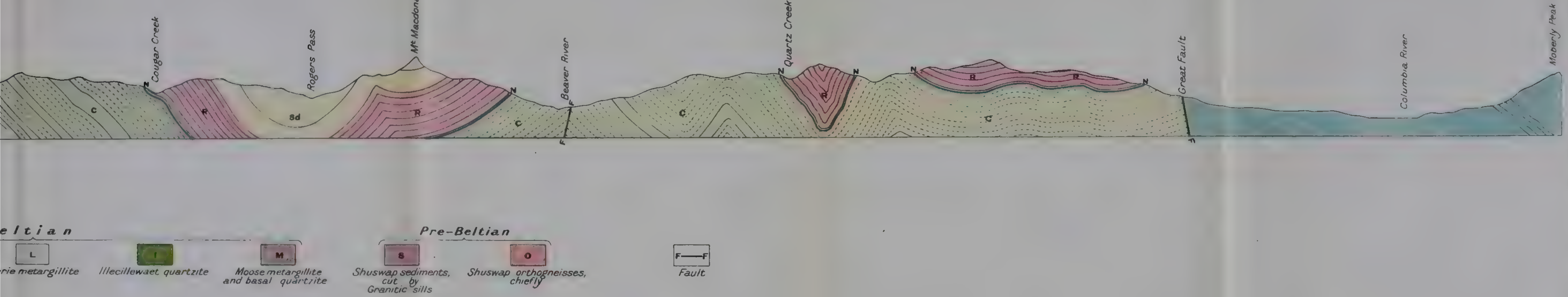
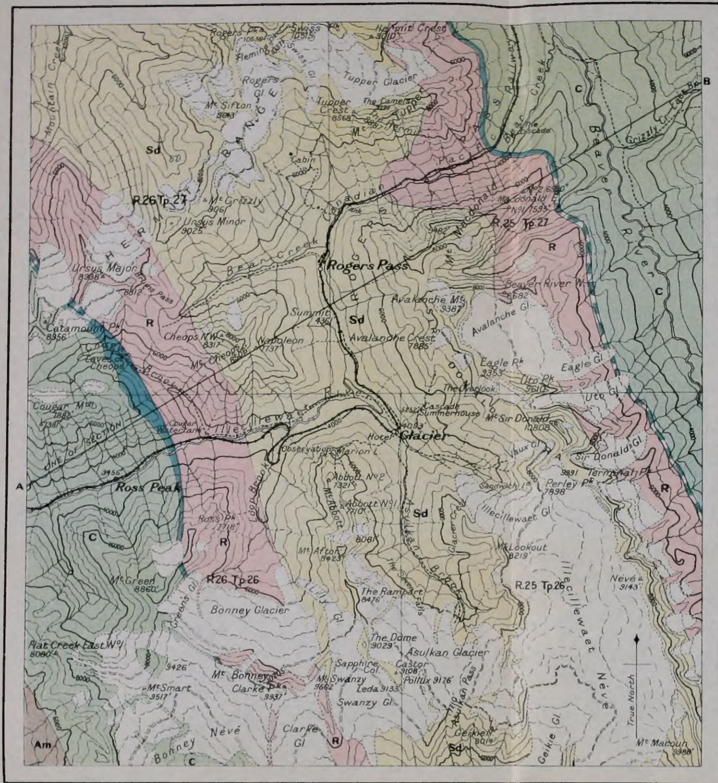


...urcell Mountains from Moberly Peak to Revelstoke

...al and Vertical scale

Miles 4 5 6 7 8 9 10

Kilometres 10 15



Geological Survey, Canada.

Legend

- Glacier and snow-field
- **Sd** Sir Donald quartzite
- **R** Ross quartzite
- Nakimu limestone
- Nakimu limestone (mapped approximately)
- **C** Cougar formation (quartzite, metargillite)
- **Am** Phyllitic metargillite Youngest member of Albert Canyon division of Selkirk series

Beltian

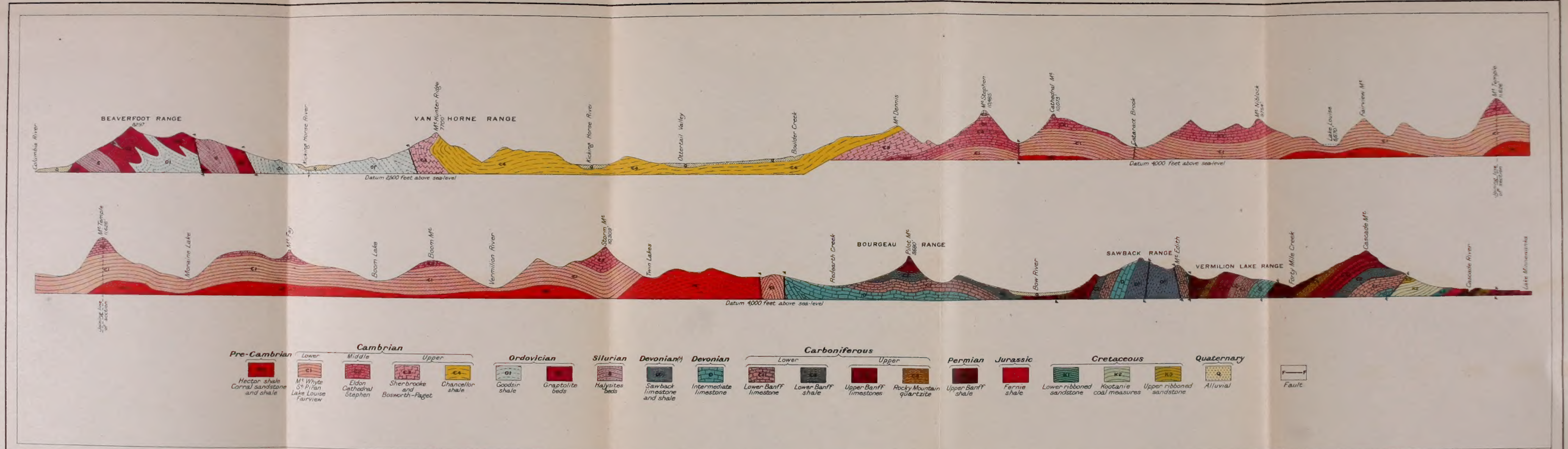
Note--Faults not shown on the map

Glacier

Miles
1 ½ 0 1 2 3 4 5

Kilometres
1 ½ 0 1 2 3 4 5

Section along line AB



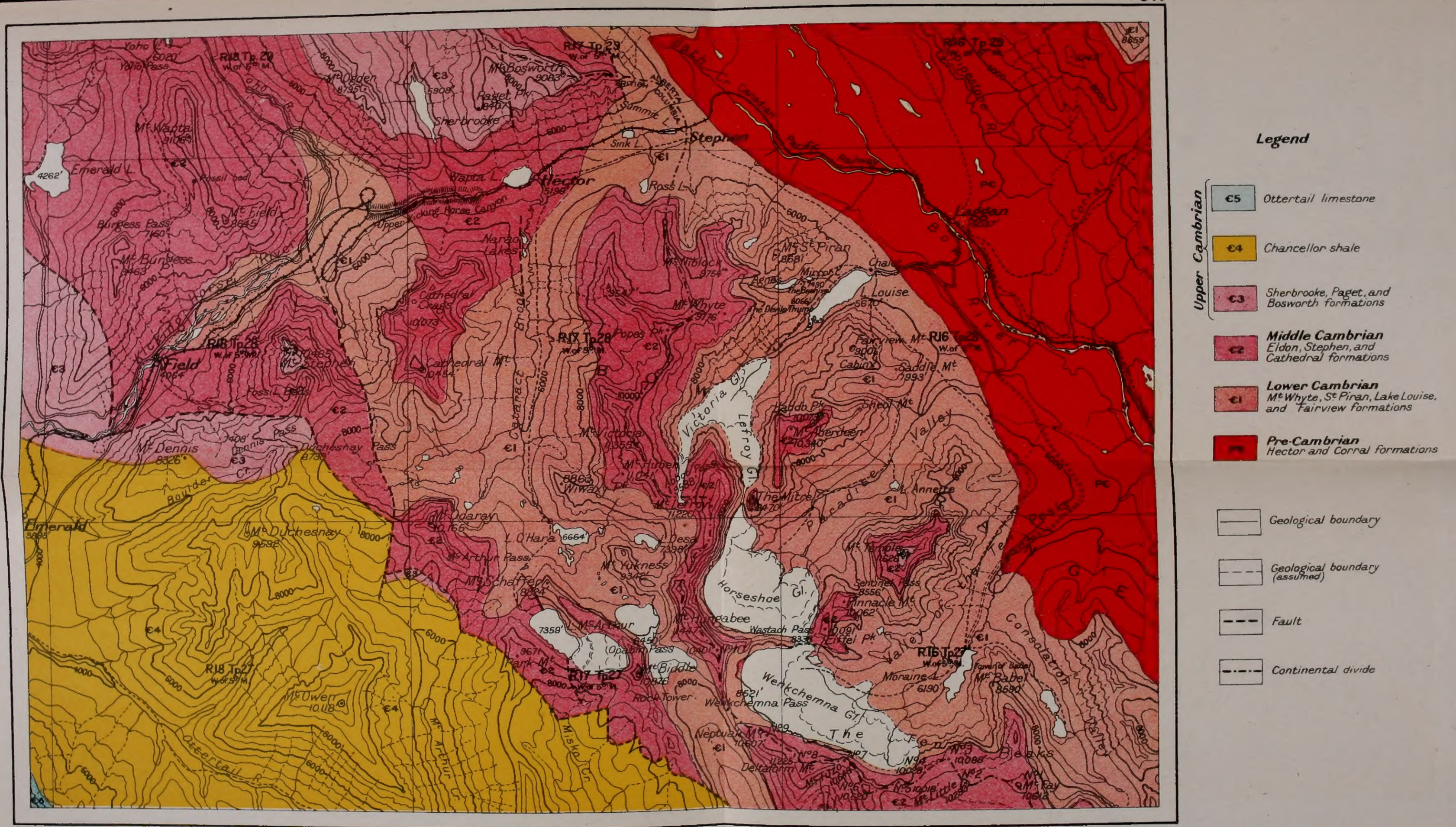
Geological Survey, Canada.

Structure Section** across the **Rocky Mountains** near the **Main Line** of the **Canadian Pacific Railway** between the **Cascade Trough** and the **Columbia Valley

Horizontal and Vertical scale

Miles

Kilometres



Geological Survey, Canada.

Laggan — Field

Miles: 1 ½ 0 1 2 3 4 5 6

Kilometres: 1 ½ 0 1 2 3 4 5 6 7 8 9 10